CONTINUITY

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ADDRESS

TO THE

BRITISH ASSOCIATION

BY

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CONTINUITY

FIRST let me lament the catastrophe which has led to my occupying the Chair here in this city. Sir William White was a personal friend of many here present, and I would that the citizens of Birmingham could have become acquainted with his attractive personality, and heard at first hand of the strenuous work which he accomplished in carrying out the behests of the Empire in the construction of its first line of defence.

Although a British Association Address is hardly an annual stocktaking, it would be improper to begin this year of office without referring to four more of our losses :—One that cultured gentleman, amateur of science in the best sense, who was chosen to preside over our Jubilee

meeting at York thirty-two years ago. Sir John Lubbock, first Baron Avebury, cultivated science in a spirit of pure enjoyment, treating it almost as one of the Arts; and he devoted social and political energy to the welfare of the multitude of his fellows less fortunately situated than himself.

Through the untimely death of Sir George Darwin the world has lost a mathematical astronomer whose work on the Tides and allied phenomena is a monument of power and achievement. So recently as our visit to S. Africa he occupied the Presidential Chair.

Within the last month I have heard of the premature death of John Milne, who was apparently at the height of his energy and usefulness. His enthusiasm and persevering work for Seismology has resulted in an international organisation centring round his personality. He has, I am told, left £1000 to help continue the work, and it behoves us to see that no sinews of war shall be lacking to assist survivors in organising and continuing the attack in this immensely important field of combined and co-operative research.

By the fourth of our major losses, I mean the death of the brilliant Mathematician of a neighbouring nation who took so comprehensive and

philosophic a grasp of the intricacies of physics, and whose eloquent though sceptical exposition of our laws and processes, and of the modifications entailed in them by recent advances, will be sure to attract still more widespread attention among all to whom the rather abstruse subject-matter is sufficiently familiar. I cannot say that I find myself in agreement with all that Henri Poincaré wrote or spoke in the domain of physics, but no physicist can help being interested in his mode of presentation; and I may have occasion to refer, in passing, to some of the topics with which he dealt.

And now, eliminating from our purview, as is always necessary, a great mass of human activity, and limiting ourselves to a scrutiny on the side of pure science alone, let us ask what, in the main, is the characteristic of the promising though perturbing period in which we live. Different persons would give different answers, but the answer I venture to give is—Rapid progress, combined with Fundamental scepticism.

Rapid progress was not characteristic of the latter half of the nineteenth century,—at least not in physics. Fine solid dynamical foundations were laid, and the edifice of knowledge was con-

solidated ; but wholly fresh ground was not being opened up, and totally new buildings were not expected.

> ' In many cases the student was led to believe that the main facts of nature were all known, that the chances of any great discovery being made by experiment were vanishingly small, and that therefore the experimentalist's work consisted in deciding between rival theories, or in finding some small residual effect, which might add a more or less important detail to the theory.'—*Schuster.*

With the realisation of predicted ether waves in 1888, the discovery of X-rays in 1895, spontaneous radioactivity in 1896, and the isolation of the electron in 1898, expectation of further achievement became vivid ; and novelties, experimental, theoretical, and speculative, have been showered upon us ever since this century began. That is why I speak of rapid progress.

Of the progress I shall say little,—there must always be some uncertainty as to which particular achievement permanently contributes to it ; but I will speak about the fundamental scepticism.

Let me hasten to explain that I do not mean the well-worn and almost antique theme of Theo-

logical scepticism: that controversy is practically in abeyance just now. At any rate the major conflict is suspended; the forts behind which the enemy has retreated do not invite attack; the territory now occupied by him is little more than his legitimate province. It is the scientific allies, now, who are waging a more or less invigorating conflict among themselves; with Philosophers joining in. Meanwhile the ancient foe is biding his time and hoping that from the struggle something will emerge of benefit to himself. Some positions, he feels, were too hastily abandoned and may perhaps be retrieved; or, to put it without metaphor, it seems possible that a few of the things prematurely denied, because asserted on inconclusive evidence, may, after all, in some form or other, have really happened. Thus the old theological bitterness is mitigated, and a temporising policy is either advocated or instinctively adopted.

To illustrate the nature of the fundamental scientific or philosophic controversies to which I do refer, would require almost as many addresses as there are Sections of the British Association; or at any rate as many as there are chief cities in Australia; and perhaps my successor in the Chair will continue the theme; but, to exhibit

my meaning very briefly, I may cite the kind of dominating controversies now extant, employing as far as possible only a single word in each case so as to emphasise the necessary brevity and insufficiency of the reference.

In Physiology the conflict rages round *Vitalism*. (My immediate predecessor dealt with the subject at Dundee.)

In Chemistry the debate concerns *Atomic structure*. (My penultimate predecessor is well aware of pugnacity in that region.)

In Biology the dispute is on the laws of *Inheritance*. (My nominated successor is likely to deal with this subject; probably in a way not deficient in liveliness.)

And besides these major controversies, debate is active in other sections :—

In Education, *Curricula* generally are being overhauled or fundamentally criticised, and revolutionary ideas are promulgated concerning the advantages of freedom for infants.

In Economic and Political Science, or Sociology, what is there that is not under discussion? Not property alone, nor land alone, but everything,—back to the garden of Eden and the inter-relations of men and women.

Lastly, in the vast group of Mathematical and Physical Sciences, ‘slurred over rather than

summed up as Section A,' present-day scepticism concerns what, if I had to express it in one word, I should call *Continuity*. The full meaning of this term will hardly be intelligible without explanation, and I shall discuss it presently.

Still more fundamental and deep-rooted than any of these sectional debates, however, a critical examination of scientific foundations generally is going on ; and a kind of philosophic scepticism is in the ascendant, resulting in a mistrust of purely intellectual processes and in a recognition of the limited scope of science.

For science is undoubtedly an affair of the intellect, it examines everything in the cold light of reason ; and that is its strength. It is a commonplace to say that science must have no likes or dislikes, must aim only at truth ; or as Bertrand Russell well puts it,—

> 'The kernel of the scientific outlook is the refusal to regard our own desires, tastes, and interests as affording a key to the understanding of the world.'

This exclusive single-eyed attitude of science is its strength ; but, if pressed beyond the positive region of usefulness into a field of dogmatic

negation and philosophising, it becomes also its weakness. For the nature of man is a large thing, and intellect is only a part of it: a recent part too, which therefore necessarily, though not consciously, suffers from some of the defects of newness and crudity, and should refrain from imagining itself the whole—perhaps it is not even the best part—of human nature.

The fact is that some of the best things are, by abstraction, excluded from Science, though not from Literature and Poetry; hence perhaps an ancient mistrust or dislike of science, typified by the Promethean legend. Science is systematised and *metrical* knowledge, and in regions where measurement cannot be applied it has small scope; or, as Mr. Balfour said the other day at the opening of a new wing of the National Physical Laboratory,

> 'Science depends on measurement, and things not measurable are therefore excluded, or tend to be excluded, from its attention. But Life and Beauty and Happiness are not measurable.' And then characteristically he adds:—'If there could be a unit of happiness, Politics might begin to be scientific.'

Emotion and Intuition and Instinct are immensely older than science, and in a comprehen-

sive survey of existence they cannot be ignored. Scientific men may rightly neglect them, in order to do their proper work, but philosophers cannot.

So Philosophers have begun to question some of the larger generalisations of science, and to ask whether in the effort to be universal and comprehensive we have not extended our laboratory inductions too far. The Conservation of Energy, for instance,—is it always and everywhere valid; or may it under some conditions be disobeyed? It would seem as if the second law of Thermodynamics must be somewhere disobeyed—at least if the age of the Universe is both ways infinite,—else the final consummation would have already arrived.

Not by philosophers only, but by scientific men also, ancient postulates are being pulled up by the roots. Physicists and Mathematicians are beginning to consider whether the long-known and well-established laws of mechanics hold true everywhere and always, or whether the Newtonian scheme must be replaced by something more modern, something to which Newton's laws of motion are but an approximation.

Indeed a whole system of non-Newtonian Mechanics has been devised, having as its founda-

tion the recently discovered changes which must occur in bodies moving at speeds nearly comparable with that of light. It turns out in fact that both Shape and Mass are functions of Velocity. As the speed increases the mass increases and the shape is distorted, though under ordinary conditions only to an infinitesimal extent.

So far I agree; I agree with the statement of fact; but I do not consider it so revolutionary as to overturn Newtonian mechanics. After all, a variation of Mass is familiar enough, and it would be a great mistake to say that Newton's second law breaks down merely because Mass is not constant. A raindrop is an example of variable mass; or the earth may be, by reason of meteoric dust; or the sun, by reason of radioactivity; or a locomotive, by reason of the emission of steam. In fact, variable masses are the commonest, for friction may abrade any moving body to a microscopic extent.

That Mass is constant is only an approximation. That Mass is equal to ratio of Force and Acceleration is a definition, and can be absolutely accurate. It holds perfectly even for an electron with a speed near that of light; and it is by means of Newton's second law that the varia-

tion of Mass with Velocity has been experimentally observed and compared with theory.

I urge that we remain with, or go back to, Newton. I see no reason against retaining all Newton's laws, discarding nothing, but supplementing them in the light of further knowledge.

Even the laws of Geometry have been overhauled, and Euclidean Geometry is seen to be but a special case of more fundamental generalisations. How far they apply to existing space, and how far Time is a reality or an illusion, and whether it can in any sense depend on the motion or the position of an observer: all these things in some form or other are discussed.

The Conservation of Matter also, that mainmast of nineteenth-century chemistry, and the existence of the Ether of Space, that sheet-anchor of nineteenth-century physics,—do they not sometimes seem to be going by the board?

Professor Schuster, in his Indian lectures, commented on the modern receptive attitude as follows:—

> 'The state of plasticity and flux—a healthy state, in my opinion,—in which scientific thought of the present day adapts itself to almost any novelty, is illustrated by the complacency with which the most

> cherished tenets of our fathers are being abandoned. Though it was never an article of orthodox faith that chemical elements were immutable and would not some day be resolved into simpler constituents, yet the conservation of mass seemed to lie at the very foundation of creation. But now-a-days the student finds little to disturb him, perhaps too little, in the idea that mass changes with velocity; and he does not always realise the full meaning of the consequences which are involved.'

This readiness to accept and incorporate new facts into the scheme of physics may have led to perhaps an undue amount of scientific scepticism, in order to right the balance.

But a still deeper variety of comprehensive scepticism exists, and it is argued that all our laws of nature, so laboriously ascertained and carefully formulated, are but conventions after all, not truths: that we have no faculty for ascertaining real truth, that our intelligence was not evolved for any such academic purpose; that all we can do is to express things in a form convenient for present purposes and employ that mode of expression as a tentative and pragmatically useful explanation.

Even *explanation*, however, has been discarded

as too ambitious by some men of science, who claim only the power to describe. They not only emphasise the *how* rather than the *why*,—as is in some sort inevitable, since explanations are never ultimate—but are satisfied with very abstract propositions, and regard mathematical equations as preferable to, because safer than, mechanical analogies or models.

> ' To use an acute and familiar expression of Gustav Kirchhoff, it is the object of science to *describe* natural phenomena, not to *explain* them. When we have expressed by an equation the correct relationship between different natural phenomena we have gone as far as we safely can, and if we go beyond we are entering on purely speculative ground.'

But the modes of statement preferred by those who distrust our power of going correctly into detail are far from satisfactory. Professor Schuster describes and comments on them thus:—

> ' Vagueness, which used to be recognised as our great enemy, is now being enshrined as an idol to be worshipped. We may never know what constitutes atoms, or what is the real structure of the ether; why trouble, therefore, it is said, to find out more about

> them? Is it not safer, on the contrary, to confine ourselves to a general talk on entropy, luminiferous vectors, and undefined symbols expressing vaguely certain physical relationships? What really lies at the bottom of the great fascination which these new doctrines exert on the present generation is sheer cowardice; the fear of having its errors brought home to it.' . . .
>
> 'I believe this doctrine to be fatal to a healthy development of science. Granting the impossibility of penetrating beyond the most superficial layers of observed phenomena, I would put the distinction between the two attitudes of mind in this way: One glorifies our ignorance, while the other accepts it as a regrettable necessity.'

With this criticism I am in accord.

In further illustration of the modern sceptical attitude, I quote from Poincaré:—

> 'Principles are conventions and definitions in disguise. They are, however, deduced from experimental laws, and these laws have, so to speak, been erected into principles to which our mind attributes an absolute value.' . . .
>
> 'The fundamental propositions of geometry, for instance Euclid's postulate, are only conventions; and it is quite as un-

reasonable to ask if they are true or false as to ask if the metric system is true or false. Only, these conventions are convenient.' . . .

'Whether the ether exists or not matters little,—let us leave that to the metaphysicians; what is essential for us is that everything happens as if it existed, and that this hypothesis is found to be suitable for the explanation of phenomena. After all, have we any other reason for believing in the existence of material objects? That, too, is only a convenient hypothesis.'

A needed antidote against over-pressing these utterances, however, is provided by Sir J. Larmor in his Preface :—

'There has been of late a growing trend of opinion, prompted in part by general philosophical views, in the direction that the theoretical constructions of physical science are largely factitious, that instead of presenting a valid image of the relations of things on which further progress can be based, they are still little better than a mirage.' . . .

'The best method of abating this scepticism is to become acquainted with the real scope and modes of application of conceptions which, in the popular language of superficial exposition—and even in the un-

> guarded and playful paradox of their authors, intended only for the instructed eye—often look bizarre enough.'

One thing is very notable, that it is closer and more exact knowledge that has led to the kind of scientific scepticism now referred to; and that the simple laws on which we used to be working were thus simple and discoverable because the full complexity of existence was tempered to our ken by the roughness of our means of observation.

Kepler's laws are not accurately true, and if he had had before him all the data now available he could hardly have discovered them. A planet does not really move in an ellipse but in a kind of hypocycloid, and not accurately in that either.

So it is also with Boyle's law, and the other simple laws in Physical Chemistry. Even Van der Waals' generalisation of Boyle's law is only a further approximation.

In most parts of physics simplicity has sooner or later to give place to complexity: though certainly I urge that the simple laws were true, and are still true, as far as they go, their inaccuracy being only detected by further real discovery. The reason they are departed from becomes known to us; the law is not really disobeyed, but is modified through the action of a known ad-

ditional cause. Hence it is all in the direction of progress.

It is only fair to quote Poincaré again, now that I am able in the main to agree with him :—

> 'Take for instance the laws of reflection. Fresnel established them by a simple and attractive theory which experiment seemed to confirm. Subsequently, more accurate researches have shown that this verification was but approximate; traces of elliptic polarisation were detected elsewhere. But it is owing to the first approximation that the cause of these anomalies was found, in the existence of a transition layer; and all the essentials of Fresnel's theory have remained. We cannot help reflecting that all these relations would never have been noted if there had been doubt in the first place as to the complexity of the objects they connect. Long ago it was said: If Tycho had had instruments ten times as precise, we would never have had a Kepler, or a Newton, or Astronomy. It is a misfortune for a science to be born too late, when the means of observation have become too perfect. That is what is happening at this moment with respect to physical chemistry: the founders are hampered in their general grasp by third and fourth decimal places; happily they are men of robust faith. As

> we get to know the properties of matter better we see that continuity reigns. . . . It would be difficult to justify [the belief in continuity] by apodeictic reasoning, but without it all science would be impossible.'

Here he touches on my own theme, *Continuity*; and, if we had to summarise the main trend of physical controversy at present, I feel inclined to urge that it largely turns on the question as to which way ultimate victory lies in the fight between Continuity and Discontinuity.

On the surface of nature at first we see discontinuity; objects detached and countable. Then we realise the air and other media, and so emphasise continuity and flowing quantities. Then we detect atoms and numerical properties, and discontinuity once more makes its appearance. Then we invent the ether and are impressed with continuity again. But this is not likely to be the end; and what the ultimate end will be, or whether there is an ultimate end, is a question difficult to answer.

The modern tendency is to emphasise the discontinuous or atomic character of everything. Matter has long been atomic, in the same sense as Anthropology is atomic; the unit of matter is the atom, as the unit of humanity is the in-

dividual.[1] Whether men or women or children —they can be counted as so many 'souls.' And atoms of matter can be counted too.

Certainly however there is an illusion of continuity. We recognise it in the case of water. It appears to be a continuous medium, and yet it is certainly molecular. It is made continuous again, in a sense, by the ether postulated in its pores; for the ether is essentially continuous. Though Osborne Reynolds, it is true, invented a discontinuous or granular Ether, on the analogy of the sea-shore. The sands of the sea, the hairs of the head, the descendants of a Patriarch, are typical instances of numerable, or rather innumerable, things. The difficulty of enumerating them is not that there is nothing to count, but merely that the things to be counted are very numerous. So are the atoms in a drop of water,—they outnumber the drops in an Atlantic Ocean,—and, during the briefest time of stating their number, fifty millions or so may have evaporated; but they are as easy to count as the grains of sand on a shore.

The process of counting is evidently a process

[1] In his recent Canadian Address, Lord Haldane emphasised the national and social continuity of the human race as opposed to individual discontinuity.

applicable to discontinuities, *i.e.*, to things with natural units; you can count apples and coins, and days and years, and people and atoms. To apply number to a continuum you must first cut it up into artificial units; and you are always left with incommensurable fractions. Thus only is it that you can deal numerically with such continuous phenomena as the warmth of a room, the speed of a bird, the pull of a rope, or the strength of a current.

But how, it may be asked, does discontinuity apply to number? The natural numbers, 1, 2, 3, etc., are discontinuous enough, but there are fractions to fill up the interstices; how do we know that they are not really connected by these fractions, and so made continuous again?

(By number I always mean commensurable number; incommensurables are not numbers: they are just what cannot be expressed in numbers. The square root of 2 is not a number, though it can be readily indicated by a length. Incommensurables are usual in physics and are frequent in geometry; the conceptions of geometry are essentially continuous. It is clear, as Poincaré says, that 'if the points whose coordinates are commensurable were alone regarded as real, the in-circle of a square and the diagonal

of the square would not intersect, since the co-ordinates of the points of intersection are in-commensurable.')

I want to explain how commensurable fractions do not connect up numbers, nor remove their discontinuity in the least. The divisions on a foot rule, divided as closely as you please, represent commensurable fractions, but they represent none of the length. No matter how numerous they are, all the length lies between them; the divisions are mere partitions and have consumed none of it; nor do they connect up with each other, they are essentially discontinuous. The interspaces are infinitely more extensive than the barriers which partition them off from one another; they are like a row of compartments with infinitely thin walls. All the incommensurables lie in the interspaces; the compartments are full of them, and they are thus infinitely more numerous than the numerically expressible magnitudes. Take any point of the scale at random, that point will certainly lie in an interspace: it will not lie on a division, for the chances are infinity to 1 against it.

Accordingly incommensurable quantities are the rule in physics. Decimals do not in practice terminate or circulate, in other words vulgar

fractions do not accidentally occur in any measurements, for this would mean infinite accuracy. We proceed to as many places of decimals as correspond to the order of accuracy aimed at.

Whenever, then, a commensurable number is really associated with any natural phenomenon, there is necessarily a noteworthy circumstance involved in the fact. and it means something quite definite and ultimately ascertainable. Every discontinuity that can be detected and counted is an addition to knowledge. It not only means the discovery of natural units instead of being dependent on artificial ones, but it throws light also on the nature of phenomena themselves.

For instance :—

The ratio between the velocity of light and the inverted square root of the product of the electric and magnetic constants was discovered by Clerk Maxwell to be 1 ; and a new volume of physics was by that discovery opened.

Dalton found that chemical combination occurred between quantities of different substances specified by certain whole or fractional numbers ; and the atomic theory of matter sprang into substantial though at first infantile existence.

The hypothesis of Prout, which in some modified form seems likely to be substantiated,

is that all atomic weights are commensurable numbers; in which case there must be a natural fundamental unit underlying, and in definite groups composing, the atoms of every form of matter.

The small number of degrees of freedom of a molecule, and the subdivision of its total energy into equal parts corresponding thereto, is a theme not indeed without difficulty but full of importance. It is responsible for the suggestion that energy too may be atomic!

Mendelejeff's series again, or the detection of a natural grouping of atomic weights in families of seven, is another example of the significance of number.

Electricity was found by Faraday to be numerically connected with quantity of matter; and the atom of electricity began its hesitating but now brilliant career.

Electricity itself—*i.e.* electric charge—strangely enough has proved itself to be atomic. There is a natural unit of electric charge, as suspected by Faraday and Maxwell and named by Johnstone Stoney. Some of the electron's visible effects were studied by Crookes in a vacuum; and its weighing and measuring by J. J. Thomson were announced to the British Association meeting at

Dover in 1899—a striking prelude to the twentieth century.

An electron is the natural unit of negative electricity, and it may not be long before the natural unit of positive electricity is found too. But concerning the nature of the positive unit there is at present some division into opposite camps. One school prefers to regard the unit of positive electricity as a homogeneous sphere, the size of an atom, in which electrons revolve in simple harmonic orbits and constitute nearly the whole effective mass. Another school, while appreciating the simplicity and ingenuity and beauty of the details of this conception, and the skill with which it has been worked out, yet thinks the evidence more in favour of a minute central positive nucleus, or nucleus-group, of practically atomic mass; with electrons, larger—*i.e.* less concentrated—and therefore less massive than itself, revolving round it in astronomical orbits. While from yet another point of view it is insisted that positive and negative electrons can only differ skew-symmetrically, one being like the image of the other in a mirror, and that the mode in which they are grouped to form an atom remains for future discovery. But no one doubts that electricity is ultimately atomic.

Even magnetism has been suspected of being atomic, and its hypothetical unit has been named in advance the *magneton:* but I confess that here I have not been shaken out of the conservative view.

We may express all this as an invasion of number into unexpected regions.

Biology may be said to be becoming atomic. It has long had natural units in the shape of cells and nuclei, and some discontinuity represented by body-boundaries and cell-walls; but now, in its laws of heredity as studied by Mendel, number and discontinuity are strikingly apparent among the reproductive cells, and the varieties of off-spring admit of numerical specification and prediction to a surprising extent; while modification by continuous variation, which seemed to be of the essence of Darwinism, gives place to, or at least is accompanied by, mutation, with finite and considerable and in appearance discontinuous change. So far from Nature not making jumps, it becomes doubtful if she does anything else. Her hitherto placid course, more closely examined, is beginning to look like a kind of steeplechase.

Yet undoubtedly Continuity is the backbone of evolution, as taught by all biologists—no

artificial boundaries or demarcations between species—a continuous chain of heredity from far below the amœba up to man. Actual continuity of undying germ-plasm, running through all generations, is taught likewise; though a strange discontinuity between this persistent element and its successive accessory body-plasms—a discontinuity which would convert individual organisms into mere temporary accretions or excretions, with no power of influencing or conveying experience to their generating cells—is advocated by one school.

Discontinuity does not fail to exercise fascination even in pure Mathematics. Curves are invented which have no tangent or differential coefficient, curves which consist of a succession of dots or of twists; and the theory of commensurable numbers seems to be exerting a dominance over philosophic mathematical thought as well as over physical problems.

And not only these fairly accepted results are prominent, but some more difficult and unexpected theses in the same direction are being propounded, and the atomic character of Energy is advocated. We had hoped to be honoured by the presence of Professor Planck, whose theory of the *quantum*, or indivisible unit or atom of energy,

excites the greatest interest, and by some is thought to hold the field. See page 36.

Then again Radiation is showing signs of becoming atomic or discontinuous. The corpuscular theory of radiation is by no means so dead as in my youth we thought it was. Some radiation is certainly corpuscular, and even the etherial kind shows indications, which may be misleading, that it is spotty, or locally concentrated into points, as if the wave-front consisted of detached specks or patches; or, as J. J. Thomson says, 'the wave-front must be more analogous to bright specks on a dark ground than to a uniformly illuminated surface,' thus suggesting that the Ether may be fibrous in structure, and that a wave runs along lines of electric force; as the genius of Faraday surmised might be possible, in his 'Thoughts on Ray Vibrations.' Indeed Newton guessed something of the same kind, I fancy, when he superposed ether-pulses on his corpuscles.

Whatever be the truth in this matter, a discussion on Radiation, of extreme weight and interest, though likewise of great profundity and technicality, is expected on Friday in Section A. We welcome Professor Lorentz, Dr. Arrhenius, Professor Jeans, Professor Pringsheim, and

others, some of whom have been specially invited to England because of the important contributions which they have made to the subject-matter of this discussion.

Why is so much importance attached to Radiation? Because it is the best-known and longest-studied link between matter and ether, and the only property we are acquainted with that affects the unmodified great mass of ether alone. Electricity and magnetism are associated with the modifications or singularities called electrons. Heat and sound are connected still more directly with matter. Radiation, however, though excited by an accelerated electron, is subsequently let loose in the ether of space, and travels as a definite thing at a measurable and constant pace—a pace independent of everything so long as the ether is free, unmodified and unloaded by matter. Hence radiation has much to teach us, and we have much to learn concerning its nature.

How far can the analogy of granular, corpuscular, countable, atomic, or discontinuous things be pressed? There are those who think it can be pressed very far. But to avoid misunderstanding let me state, for what it may be worth, that I myself am an upholder of *ultimate* Continuity, and a fervent believer in the Ether of Space.

We have already learnt something about the ether; and although there may be almost as many varieties of opinion as there are people qualified to form one, in my view we have learnt as follows:—

The Ether is the universal connecting medium which binds the universe together, and makes it a coherent whole instead of a chaotic collection of independent isolated fragments. It is the vehicle of transmission of all manner of force, from gravitation down to cohesion and chemical affinity; it is therefore the storehouse of potential energy.

Matter moves, but Ether is strained.

What we call elasticity of matter is only the result of an alteration of configuration due to movement and readjustment of particles, but all the strain and stress are in the ether. The ether itself does not move, that is to say it does not move in the sense of locomotion, though it is probably in a violent state of rotational or turbulent motion in its smallest parts; and to that motion its exceeding rigidity is due.

As to its density, it must be far greater than that of any form of matter, millions of times denser than lead or platinum. Yet matter moves through it with perfect freedom, without any

friction or viscosity. There is nothing paradoxical in this: viscosity is not a function of density; the two are not necessarily connected. When a solid moves through an alien fluid it is true that it acquires a spurious or apparent extra inertia from the fluid it displaces; but, in the case of matter and ether, not only is even the densest matter excessively porous and discontinuous, with vast interspaces in and among the atoms, but the constitution of matter is such that there appears to be no displacement in the ordinary sense at all; the ether is itself so modified as to *constitute* the matter in some way. Of course that portion moves, its inertia is what we observe, and its amount depends on the potential energy in its associated electric field, but the motion is not like that of a foreign body, it is that of some inherent and merely individualised portion of the stuff itself. Certain it is that the ether exhibits no trace of viscosity.[1]

Matter in motion, Ether under strain, constitute the fundamental concrete things we have to do with in physics. The first pair represent

[1] For details of my experiment on this subject see 'Phil. Trans. Roy. Soc.' for 1893 and 1897; or a very abbreviated reference to it, and to the other matters above-mentioned, in my small book 'The Ether of Space.'

kinetic energy, the second potential energy; and all the activities of the material universe are represented by alternations from one of these forms to the other.

Whenever this transference and transformation of energy occur, work is done, and some effect is produced, but the energy is never diminished in quantity: it is merely passed on from one body to another, always from ether to matter or vice versa,—except in the case of radiation, which simulates matter—and from one form to another.

The forms of energy can be classified as either a translation, a rotation, or a vibration, of pieces of matter of different sizes, from stars and planets down to atoms and electrons; or else an etherial strain which in various different ways is manifested by the behaviour of such masses of matter as appeal to our senses.[1]

Some of the facts responsible for the suggestion that energy is atomic seem to me to depend on the discontinuous nature of the structure of a material atom, and on the high velocity of its constituent particles. The apparently discontinuous emission of radiation is, I believe, due to features in the real discontinuity of matter.

[1] See, in the 'Philosophical Magazine' for October, 1879, my article on a Classification of the forms of energy.

Disturbances inside an atom appear to be essentially catastrophic ; a portion is liable to be ejected with violence. There appears to be a critical velocity below which ejection does not take place ; and, when it does, there also occurs a sudden rearrangement of parts which is presumably responsible for some perceptible etherial radiation. Hence it is, I suppose, that radiation comes off in gushes or bursts ; and hence it appears to consist of indivisible units. The occasional phenomenon of new stars, as compared with the steady orbital motion of the millions of recognised bodies, may be suggested as an astronomical analogue.

The hypothesis of *quanta* was devised to reconcile the law that the energy of a group of colliding molecules must in the long run be equally shared among all their degrees of freedom, with the observed fact that the energy is really shared into only a small number of equal parts. For if vibration-possibilities have to be taken into account, the number of degrees of molecular freedom must be very large, and energy shared among them ought soon to be all frittered away ; whereas it is not. Hence the idea is suggested that minor degrees of freedom are initially excluded from sharing the energy, because they cannot be supplied with less than one atom of it.

I should prefer to express the fact by saying that the ordinary encounters of molecules are not of a kind able to excite atomic vibrations, or in any way to disturb the ether. Spectroscopic or luminous vibrations of an atom are excited only by an exceptionally violent kind of collision, which may be spoken of as chemical clash; the ordinary molecular orbital encounters, always going on at the rate of millions a second, are ineffective in that respect, except in the case of phosphorescent or luminescent substances. That common molecular deflexions *are* ineffective is certain, else all the energy would be dissipated or transferred from matter into the ether; and the reasonableness of their radiative inefficiency is not far to seek, when we consider the comparatively leisurely character of molecular movements, at speeds comparable with the velocity of sound. Admittedly, however, the effective rigidity of molecules must be complete, otherwise the sharing of energy must ultimately occur. They do not seem able to be set vibrating by anything less than a certain minimum stimulus; and that is the basis for the theory of *quanta*.

Quantitative applications of Planck's theory, to elucidate the otherwise shaky stability of the astronomically constituted atom, have been made;

and the agreement between results so calculated and those observed, including a determination of series of spectrum lines, is very remarkable. One of the latest contributions to this subject is a paper by Dr. Bohr in the 'Philosophical Magazine' for July this year.

To show that I am not exaggerating the modern tendency towards discontinuity, I quote, from M. Poincaré's 'Dernières Pensées,' a proposition which he announces in italics as representing a form of Professor Planck's view of which he apparently approves :—

> 'A physical system is susceptible of a finite number only of distinct conditions; it jumps from one of these conditions to another without passing through a continuous series of intermediate conditions.'

Also this from Sir Joseph Larmor's Preface to Poincaré's 'Science and Hypothesis' :—

> 'Still more recently it has been found that the good Bishop Berkeley's logical jibes against the Newtonian ideas of fluxions and limiting ratios cannot be adequately appeased in the rigorous mathematical conscience, until our apparent continuities are resolved mentally into discrete aggregates which we only partially apprehend. The irresistible

impulse to atomise everything thus proves to be not merely a disease of the physicist: a deeper origin, in the nature of knowledge itself, is suggested.'

One very valid excuse for this prevalent attitude is the astonishing progress that has been made in actually seeing or almost seeing the molecules, and studying their arrangement and distribution.

The laws of gases have been found to apply to emulsions and to fine powders in suspension, of which the Brownian movement has long been known. This movement is caused by the orthodox molecular bombardment, and its average amplitude exactly represents the theoretical mean free path calculated from the 'molecular weight' of the relatively gigantic particles. The behaviour of these microscopically visible masses corresponds closely and quantitatively with what could be predicted for them as fearfully heavy atoms, on the kinetic theory of gases; they may indeed be said to constitute a gas with a gram-molecule as high as 200,000 tons; and, what is rather important as well as interesting, they tend visibly to verify the law of equipartition of energy even in so extreme a case, when that law is properly stated and applied.

Still more remarkable—the application of X-rays to display the arrangement of molecules in crystals, and ultimately the arrangement of atoms in molecules, as initiated by Professor Laue with Drs. Friedrich and Knipping, and continued by Professor Bragg and his son and by Dr. Tutton, constitute a series of researches of high interest and promise. By this means many of the theoretical anticipations of our countryman, Mr. William Barlow, and—working with him—Professor Pope, as well as of those distinguished crystallographers von Groth and von Fedorow, have been confirmed in a striking way. These brilliant researches, which seem likely to constitute a branch of Physics in themselves, and which are being continued by Messrs. Moseley and C. G. Darwin, and by Mr. Keene and others, may be called an apotheosis of the atomic theory of matter.

One other controversial topic I shall touch upon in the domain of physics, though I shall touch upon it lightly, for it is not a matter for easy reference as yet. If the 'Principle of Relativity' in an extreme sense establishes itself, it seems as if even Time would become discontinuous and be supplied in atoms, as money is doled out in pence or centimes instead of con-

tinuously;—in which case our customary existence will turn out to be no more really continuous than the events on a kinematograph screen;—while that great agent of continuity, the Ether of Space, will be relegated to the museum of historical curiosities.

In that case differential equations will cease to represent the facts of nature, they will have to be replaced by Finite Differences, and the most fundamental revolution since Newton will be inaugurated.

Now in all the debatable matters of which I have indicated possibilities I want to urge a conservative attitude. I accept the new experimental results on which some of these theories—such as the Principle of Relativity—are based, and am profoundly interested in them, but I do not feel that they are so revolutionary as their propounders think. I see a way to retain the old and yet embrace the new, and I urge moderation in the uprooting and removal of landmarks.

And of these the chief is Continuity. I cannot imagine the exertion of mechanical force across empty space, no matter how minute; a continuous medium seems to me essential. I cannot admit discontinuity in either Space or Time, nor can I imagine any sort of experiment which would

justify such a hypothesis. For surely we must realise that we know nothing experimental of either space or time, we cannot modify them in any way. We make experiments on bodies, and only on bodies, using ‘ body ’ as an exceedingly general term.

We have no reason to postulate anything but continuity for space and time. We cut them up into conventional units for convenience sake, and those units we can count ; but there is really nothing atomic or countable about the things themselves. We can count the rotations of the earth, or the revolutions of an electron, or the vibrations of a pendulum, or the waves of light. All these are concrete and tractable physical entities ; but space and time are ultimate data, abstractions based on experience. We know them through motion, and through motion only, and motion is essentially continuous. We ought clearly to discriminate between things themselves and our mode of measuring them. Our measures and perceptions may be affected by all manner of incidental and trivial causes, and we may get confused or hampered by our own movement ; but there need be no such complication in things themselves, any more than a landscape is distorted by looking at it through an irregular

window-pane or from a travelling coach. It is an ancient and discarded fable that complications introduced by the motion of an observer are real complications belonging to the outer universe.

Very well, then, what about the Ether; is that in the same predicament ? Is that an abstraction, or a mere convention, or is it a concrete physical entity on which we can experiment ?

Now it has to be freely admitted that it is exceedingly difficult to make experiments on the ether. It does not appeal to sense, and we know no means of getting hold of it. The one thing we know metrical about it is the velocity with which it can transmit transverse waves. That is clear and definite, and thereby to my judgment it proves itself a physical agent ; not indeed tangible or sensible, but yet concretely real.

But it does elude our laboratory grasp. If we rapidly move matter through it, hoping to grip it and move it too, we fail : there is no mechanical connexion. And even if we experiment on light we fail too. So long as transparent matter is moving relatively to us, light can be affected inside that matter ; but when matter is relatively stationary to matter nothing observable takes place, however fast things may be moving, so long as they move together.

Hence arises the idea that motion with respect to Ether is meaningless: and the fact that only relative motion of pieces of matter with respect to each other has so far been observed is the foundation of the Principle of Relativity. It sounds simple enough as thus stated, but in its developments it is an ingenious and complicated doctrine embodying surprising consequences which have been worked out by Professor Einstein and his disciples with consummate ingenuity.

What have I to urge against it? Well, in the first place, it is only in accordance with common sense that no effect of the first order can be observed without relative motion of matter. An Ether-stream through our laboratories is optically and electrically undetectable, at least as regards first-order observation; this is clearly explained for general readers in my book 'The Ether of Space,' Chapter IV. But the Principle of Relativity says more than that, it says that no effect of any order of magnitude can ever be observed, without the relative motion of matter.

The truth underlying this doctrine is that absolute motion without reference to *anything* is unmeaning. But the narrowing down of 'anything' to mean any piece of matter is il-

legitimate. The nearest approach to absolute motion that we can physically imagine is motion through or with respect to the Ether of Space. It is natural to assume that the Ether is on the whole stationary, and to use it as a standard of rest; in that sense motion with reference to it may be called absolute, but in no other sense.

The Principle of Relativity claims that we can never ascertain such motion: in other words it practically or pragmatically denies the existence of the Ether. Every one of our scientifically observed motions, it says, are of the same nature as our popularly observed ones, viz., motion of pieces of matter relatively to each other; and that is all that we can ever know. Everything goes on—says the Principle of Relativity—as if the Ether did not exist.

Now the facts are that no motion with reference to the ether alone has ever yet been observed: there are always curious compensating effects which just cancel out the movement-terms and destroy or effectively mask any phenomenon that might otherwise be expected. When matter moves past matter observation can be made; but, even so, no consequent locomotion of ether, outside the actually moving particles, can be detected.

(It is sometimes urged that rotation is a kind of absolute motion that can be detected, even in isolation. It can so be detected, as Newton pointed out; but in cases of rotation matter on one side the axis is moving in the opposite direction to matter on the other side of the axis; hence rotation involves relative material motion, and therefore can be observed.)

To detect motion through ether we must use an etherial process. We may use radiation, and try to compare the speeds of light along or across the motion; or we might try to measure the speed, first with the motion and then against it. But how are we to make the comparison? If the time of emission from a distant source is given by a distant clock, that clock must be observed through a telescope, that is by a beam of light; which is plainly a compensating process. Or the light from a neighbouring source can be sent back to us by a distant mirror; when again there will be compensation. Or the starting of light from a distant terrestrial source may be telegraphed to us, either with a wire or without; but it is the ether that conveys the message in either case, so again there will be compensation. Electricity, Magnetism, and Light, are all effects of the ether.

Use Cohesion, then; have a rod stretching from one place to another, and measure that. But cohesion is transmitted by the ether too, if, as believed, it is the universal binding medium. Compensation is likely; compensation can, on the electrical theory of matter, be predicted.

Use some action not dependent on Ether, then. Very well, where shall we find it?

To illustrate the difficulty I will quote a sentence from Sir Joseph Larmor's paper before the International Congress of Mathematicians at Cambridge last year.

> 'If it is correct to say with Maxwell that all radiation is an electrodynamic phenomenon, it is equally correct to say with him that all electrodynamic relations between material bodies are established by the operation, on the molecules of those bodies, of fields of force which are propagated in free space as radiation and in accordance with the laws of radiation, from one body to the other.'

The fact is we are living in an epoch of some very comprehensive generalisations. The physical discovery of the twentieth century, so far, is the Electrical Theory of Matter. This is the great new theory of our time; it was referred to,

in its philosophical aspect, by Mr. Balfour in his Presidential Address at Cambridge in 1904. We are too near to it to be able to contemplate it properly; it has still to establish itself and to develop in detail, but I anticipate that in some form or other it will prove true.[1]

Here is a briefest possible summary of the first chapter (so to speak) of the Electrical Theory of Matter.

(1) Atoms of Matter are composed of electrons,—of positive and negative electric charges.

(2) Atoms are bound together into molecules by chemical affinity which is intense electrical attraction at ultra-minute distances.

(3) Molecules are held together by cohesion, which I for one regard as residual or differential chemical affinity over molecular distances.

(4) Magnetism is due to the locomotion of electrons. There is no magnetism without an electric current, atomic or otherwise. There is no electric current without a moving electron.

[1] For a general introductory account of the electrical theory of matter my Romanes lecture for 1903 (Clarendon Press) may be referred to.

(5) Radiation is generated by every accelerated electron, in amount proportional to the square of its acceleration; and there is no other kind of radiation, except indeed a corpuscular kind; but this depends on the velocity of electrons, and therefore again can only be generated by their acceleration.

The theory is bound to have curious consequences; and already it has contributed to some of the uprooting and uncertainty that I speak of. For, if it be true, every material interaction will be electrical, *i.e.*, etherial; and hence arises our difficulty. Every kind of force is transmitted by the ether, and hence, so long as all our apparatus is travelling together at one and the same pace, we have no chance of detecting the motion. That is the strength of the Principle of Relativity. The changes are not zero, but they cancel each other out of observation.

Many forms of statement of the famous Michelson-Morley experiment are misleading. It is said to prove that the time taken by light to go with the ether stream is the same as that taken to go against or across it. It does not show that. What it shows is that the time taken by light to travel to and fro on a measured interval

fixed on a rigid block of matter is independent of the aspect of that block with respect to any motion of the earth through space. A definite and most interesting result: but it may be, and often is, interpreted loosely and too widely.

It is interpreted too widely, as I think, when Professor Einstein goes on to assume that no non-relative motion of matter can be ever observed even when *light* is brought into consideration. The relation of light to matter is very curious. The wave front of a progressive wave simulates many of the properties of matter. It has energy, it has momentum, it exerts force, it sustains reaction. It has been described as a portion of the mass of a radiating body,—which gives it a curiously and unexpectedly corpuscular 'feel.' But it has a definite velocity. Its velocity in space relative to the ether is an absolute constant independent of the motion of the source. This would not be true for corpuscular light.

Hence I hold that here is something with which our own motion may theoretically be compared; and I predict that our motion through the ether will some day be detected by help of this very fact,—by comparing our speed with that of light: though the old astronomical aberration, which seemed to make the comparison easy,

failed to do so quite simply, because it is complicated by the necessity of observing the position of a distant source, in relation to which the earth is moving. If the source and observer are moving together there is no possibility of observing aberration. Nevertheless I maintain that when matter is moving near a beam of light we may be able to detect the motion. For the velocity of light in space is no function of the velocity of the source, nor of matter near it; it is quite unaffected by motion of source or receiver. Once launched it travels in its own way. If we are travelling to meet it, it will be arriving at us more quickly; if we travel away from it, it will reach us with some lag. That is certain; and observation of the acceleration or retardation is made by aid of Jupiter's satellites. We have there the dial of a clock, to or from which we advance or recede periodically. It gains while we approach it, it loses while we recede from it, it keeps right time when we are stationary or only moving across the line of sight.

But then of course it does not matter whether Jupiter is standing still and we are moving, or vice versa: it is a case of relative motion of matter again. So it is if we observe a Doppler effect from the right and left hand limbs of the rotat-

ing sun. True, and if we are to permit no relative motion of matter we must use a terrestrial source clamped to the earth as our receiver is. And now we shall observe nothing.

But not because there is nothing to observe. Lag must really occur if we are running away from the light, even though the source is running after us at the same pace: unless we make the assumption,—true only for corpuscular light,—that the velocity of light is not an absolute thing, but is dependent on the speed of the source. With corpuscular light there is nothing to observe; with wave light there is something, but we cannot observe it.

But if the whole solar system is moving through the ether I see no reason why the relative ether drift should not be observed by a differential residual effect in connexion with Jupiter's satellites or the right and left limbs of the sun. The effect must be too small to observe without extreme precision, but theoretically it ought to be there. Inasmuch however as relative motion of matter with respect to the observer is involved in these effects, it may be held that the detection of a uniform drift of the solar system in this way is not contrary to the Principle of Relativity. It is contrary to some statements of that Principle;

and the cogency of those statements breaks down, I think, whenever they include the velocity of light; because there we really have something absolute (in the only sense in which the term can have a physical meaning) with which we can compare our own motion, when we have learnt how.

But in ordinary astronomical translation—translation as of the earth in its orbit—all our instruments, all our standards, the whole contents of our laboratory, are moving at the same rate in the same direction; under those conditions we cannot expect to observe anything. Clerk Maxwell went so far as to say that if every particle of matter simultaneously received a graduated blow so as to produce a given constant acceleration all in the same direction, we should be unaware of the fact. He did not then know all that we know about radiation. But apart from that, and limiting ourselves to comparatively slow changes of velocity, our standards will inevitably share whatever change occurs. So far as observation goes, everything will be practically as if no change had occurred at all;—though that may not be the truth. All that experiment establishes is that there have so far always been compensations; so that the attempt to observe motion through the ether is being given up as hopeless.

Surely, however, the minute and curious compensations cannot be accidental, they must be necessary? Yes, they are necessary; and I want to say why. Suppose the case were one of measuring thermal expansion; and suppose everything had the same temperature and the same expansibility; our standards would contract or expand with everything else, and we could observe nothing; but expansion would occur nevertheless. That is obvious, but the following assertion is not so obvious. If everything in the Universe had the same temperature, no matter what that temperature was, nothing would be visible at all; the external world, so far as vision went, would not appear to exist. Visibility depends on radiation, on differential radiation. We must have differences to appeal to our senses, they are not constructed for uniformity.

It is the extreme omnipresence and uniformity and universal agency of the ether of space that makes it so difficult to observe. To observe anything you must have differences. If all actions at a distance are conducted at the same rate through the ether, the travel of none of them can be observed. Find something not conveyed by the ether and there is a chance. But then

every physical action is transmitted by the ether, and in every case by means of its transverse or radiation-like activity.

Except perhaps Gravitation. That may give us a clue some day, but at present we have not been able to detect its speed of transmission at all. No plan has been devised for measuring it. Nothing short of the creation or destruction of matter seems likely to serve: creation or destruction of the gravitational unit, whether it be an atom or an electron or whatever it is. Most likely the unit of weight is an electron, just as the unit of mass is.

The so-called non-Newtonian Mechanics, with mass and shape a function of velocity, is an immediate consequence of the electrical theory of matter. The dependence of inertia and shape on speed is a genuine discovery and, I believe, a physical fact. The Principle of Relativity would reduce it to a conventional fiction. It would seek to replace this real change in matter by imaginary changes in time. But surely we must admit that Space and Time are essentially unchangeable: they are not at the disposal even of mathematicians; though it is true that Pope Gregory, or a Daylight-saving Bill, can play with our units, can turn the 3rd of October in any one year into the

14th, or can make the sun South sometimes at eleven o'clock, sometimes at twelve.[1]

But the changes of dimension and mass due to velocity are not conventions but realities; so I urge, on the basis of the electrical theory of matter. The Fitzgerald-Lorentz hypothesis I have an affection for; I was present at its birth. Indeed I assisted at its birth; for it was in my study at 21 Waverley Road, Liverpool, with Fitzgerald in an arm-chair, and while I was enlarging on the difficulty of reconciling the then new Michelson experiment with the theory of astronomical aberration and with other known facts, that he made his brilliant surmise:—'Perhaps the stone slab was affected by the motion.' I rejoined that it was a 45° shear that was needed. To which he replied, 'Well that's all right,—a simple distortion.' And very soon he said, 'And I believe it occurs, and that the Michelson experiment demonstrates it.' A shortening long-ways, or a lengthening cross-ways would do what was wanted. (See 'Nature' for 16 June, 1892.)

[1] In the historical case of governmental interference with the calendar, no wonder the populace rebelled. Surely someone might have explained to the authorities that dropping leap-year for the greater part of a century would do all that was wanted, and that the horrible inconvenience of upsetting all engagements and shortening a single year by eleven days could be avoided.

And is such a hypothesis gratuitous? Not at all: in the light of the electrical theory of matter such an effect ought to occur. The amount required by the experiment, and given by the theory, is equivalent to a shrinkage of the earth's diameter by rather less than three inches, in the line of its orbital motion through the ether of space. An oblate spheroid with the proper eccentricity has all the simple geometrical properties of a stationary sphere; the eccentricity depends in a definite way on speed, and becomes considerable as the velocity of light is approached.

All this Professors Lorentz and Larmor very soon after, and quite independently, perceived; though this is only one of the minor achievements in the electrical theory of matter which we owe to our distinguished visitor Professor H. A. Lorentz.

The key of the position, to my mind, is the nature of cohesion. I regard cohesion as residual chemical affinity, a balance of electrical attraction over repulsion between groups of alternately charged molecules. Lateral electrical attraction is diminished by motion; so is lateral electric repulsion. In cohesion both are active, and they nearly balance. At anything but molecular dis-

tance they quite balance, but at molecular distance attraction predominates. It is the diminution of the predominant partner that will be felt. Hence while longitudinal cohesion, or cohesion in the direction of motion, remains unchanged, lateral cohesion is less; so there will be distortion, and a unit cube x y z moving along x with velocity u becomes a parallelopiped with sides $1/k^2$, k, k; where $1/k^6 = 1 - u^2/v^2$.[1]

The electrical theory of matter is a positive achievement, and has positive results. By its aid we make experiments which throw light upon the relation between matter and the Ether of Space. The Principle of Relativity, which seeks to replace it, is a principle of negation, a negative proposition, a statement that observation of certain facts can never be made, a denial of any relation between matter and ether, a virtual denial that the ether exists. Whereas if we admit the real changes that go on by reason of rapid

[1] Different modes of estimating the change give slightly different results; some involve a compression as well as a distortion—in fact the strain associated with the name of Thomas Young; the details are rather complicated and this is not the place to discuss them. A pure distortion, as specified in the text, is simplest, it appears to be in accord with all the experimental facts—including some careful measurements by Bucherer,—and I rather expect it to survive.

motion, a whole field is open for discovery; it is even possible to investigate the changes in shape of an electron—appallingly minute though it is—as it approaches the speed of light; and properties belonging to the Ether of Space, evasive though it be, cannot lag far behind.

Speaking as a physicist I must claim the Ether as peculiarly our own domain. The study of molecules we share with the chemist, and matter in its various forms is investigated by all men of science, but a study of the ether of space belongs to physics only. I am not alone in feeling the fascination of this portentous entity. Its curiously elusive and intangible character, combined with its universal and unifying permeance, its apparently infinite extent, its definite and perfect properties, make the ether the most interesting as it is by far the largest and most fundamental ingredient in the material cosmos.

As Sir J. J. Thomson said at Winnipeg—

> 'The ether is not a fantastic creation of the speculative philosopher; it is as essential to us as the air we breathe. . . . The study of this all-pervading substance is perhaps the most fascinating and important duty of the physicist.'

Matter it is not, but material it is ; it belongs to the material universe and is to be investigated by ordinary methods. But to say this is by no means to deny that it may have mental and spiritual functions to subserve in some other order of existence, as Matter has in this.

The ether of space is at least the great engine of continuity. It may be much more, for without it there could hardly be a material universe at all. Certainly, however, it is essential to continuity ; it is the one all-permeating substance that binds the whole of the particles of matter together. It is the uniting and binding medium without which, if matter could exist at all, it could only exist as chaotic and isolated fragments : and it is the universal medium of communication between worlds and between particles. And yet it is possible for people to deny its existence, because it is unrelated to any of our senses,—except sight, and to that only in an indirect and not easily recognised fashion.

To illustrate the thorough way in which we may be unable to detect what is around us unless it has some link or bond which enables it to make appeal, let me make another quotation from Sir J. J. Thomson's Address at Winnipeg in 1909. He is leading up to the fact that even single

atoms, provided they are fully electrified with the proper atomic charge, can be detected by certain delicate instruments—their field of force bringing them within our ken—whereas a whole crowd of unelectrified ones would escape observation.

> 'The smallest quantity of unelectrified matter ever detected is probably that of neon, one of the inert gases of the atmosphere. Professor Strutt has shown that the amount of neon in 1/20 of a cubic centimetre of the air at ordinary pressures can be detected by the spectroscope; Sir William Ramsay estimates that the neon in the air only amounts to one part of neon in 100,000 parts of air, so that the neon in 1/20 of a cubic centimetre of air would only occupy at atmospheric pressure a volume of half a millionth of a cubic centimetre. When stated in this form the quantity seems exceedingly small, but in this small volume there are about ten million million molecules. Now the population of the earth is estimated at about fifteen hundred millions, so that the smallest number of molecules of neon we can identify is about 7,000 times the population of the earth. In other words, if we had no better test for the existence of a man than we have for that of an unelectrified molecule we should come to the conclusion that the earth is uninhabited.'

The parable is a striking one, for on these lines it might legitimately be contended that we have no right to say positively that even space is uninhabited. All we can safely say is that we have no means of detecting the existence of non-planetary immaterial dwellers, and that unless they have some link or bond with the material they must always be physically beyond our ken. We may therefore for practical purposes legitimately treat them as non-existent until such link is discovered, but we should not dogmatise about them. True agnosticism is legitimate, but not the dogmatic and positive and gnostic variety.

For I hold that Science is incompetent to make comprehensive denials, even about the Ether, and that it goes wrong when it makes the attempt. Science should not deal in negations: it is strong in affirmations, but nothing based on abstraction ought to presume to deny outside its own region. It often happens that things abstracted from and ignored by one branch of science may be taken into consideration by another:—

Thus, Chemists ignore the Ether.

Mathematicians may ignore experimental difficulties.

Physicists ignore and exclude live things.

Biologists exclude Mind and Design.

Psychologists may ignore human origin and human destiny.

Folk-lore students and comparative Mythologists need not trouble about what modicum of truth there may be in the legends which they are collecting and systematising.

And Microscopists may ignore the stars.

Yet none of these ignored things should be denied.

Denial is no more infallible than assertion. There are cheap and easy kinds of scepticism, just as there are cheap and easy kinds of dogmatism ; in fact scepticism can become viciously dogmatic, and science has to be as much on its guard against personal predilection in the negative as in the positive direction. An attitude of universal denial may be very superficial.

> 'To doubt everything or to believe everything are two equally convenient solutions ; both dispense with the necessity of reflection.'

All intellectual processes are based on abstraction,—that is on concentrated attention directed to a selected portion, with limitation of scope, and elimination of whatever may be regarded as unessential or irrelevant. For instance, History

must ignore a great multitude of facts in order to treat any intelligently: it selects. So does Art; and that is why a drawing is clearer than reality. Science makes a diagram of reality, displaying the works, like a skeleton clock. Anatomists dissect out the nervous system, the blood-vessels, and the muscles, and depict them separately,—there must be discrimination for intellectual grasp,—but in life they are all merged and co-operating together; they do not really work separately, though they may be studied separately. A scalpel discriminates: a dagger or a bullet crashes through everything. That is life,—or rather death. The laws of nature are a diagrammatic framework, analysed or abstracted out of the full comprehensiveness of reality.

Hence it is that Science has no authority in denials. To deny effectively needs much more comprehensive knowledge than to assert. And abstraction is essentially not comprehensive: one cannot have it both ways. Science employs the methods of abstraction and thereby makes its discoveries.

The reason why some physiologists insist so strenuously on the validity and self-sufficiency of the laws of physics and chemistry, and resist the temptation to appeal to unknown causes—even

though the guiding influence and spontaneity of living things are occasionally conspicuous as well as inexplicable—is that they are keen to do their proper work; and their proper work is to pursue the laws of ordinary physical Energy into the intricacies of 'colloidal electrolytic structures of great chemical complexity' and to study its behaviour there.

What we have clearly to grasp, on their testimony, is that for all the terrestrial manifestations of life the ordinary physical and chemical processes have to serve. There are not new laws for living matter, and old laws for non-living, the laws are the same; or if ever they differ, the burden of proof rests on him who sustains the difference. The conservation of energy, the laws of chemical combination, the laws of electric currents, of radiation, etc., etc.,—all the laws of Chemistry and Physics,—may be applied without hesitation in the Organic domain. Whether they are sufficient is open to question, but as far as they go they are necessary; and it is the business of the physiologist to seek out and demonstrate the action of those laws in every vital action.

This is clearly recognised by the leaders, and in the definition of Physiology by Burdon Sanderson he definitely limited it to the study of 'ascer-

tainable characters of a chemical and physical type.' In his Address to the Sub-section of Anatomy and Physiology at York in 1881 he spoke as follows :—

> 'It would give you a true idea of the nature of the great advance which took place about the middle of this century if I were to define it as the epoch of the death of "vitalism." Before that time, even the greatest biologists—*e.g.* J. Müller—recognised that the knowledge biologists possessed both of vital and physical phenomena was insufficient to refer both to a common measure. The method, therefore, was to study the processes of life in relation to each other only. Since that time it has become fundamental in our science not to regard any vital process as understood at all unless it can be brought into relation with physical standards, and the methods of physiology have been based exclusively on this principle. The most efficient cause [conducing to the change] was the progress which had been made in physics and chemistry, and particularly those investigations which led to the establishment of the doctrine of the Conservation of Energy.' . . .
>
> 'Investigators who are now working with such earnestness in all parts of the world for the advance of physiology, have before

> them a definite and well-understood purpose, that purpose being to acquire an exact knowledge of the chemical and physical processes of animal life and of the self-acting machinery by which they are regulated for the general good of the organism. The more singly and straightforwardly we direct our efforts to these ends, the sooner we shall attain to the still higher purpose—the effectual application of our knowledge for the increase of human happiness.'

Professor Gotch, whose recent loss we have to deplore, puts it even more strongly :—

> 'It is essentially unscientific,' he says, 'to say that any physiological phenomenon is caused by vital force.'

I observe that by some critics I have been called a vitalist, and in a sense I am ; but I am not a vitalist if vitalism means an appeal to an undefined 'vital force' (an objectionable term I have never thought of using) as against the laws of Chemistry and Physics. Those laws must be supplemented, but need by no means be superseded. The business of science is to trace out their mode of action everywhere, as far and as fully as possible ; and it is a true instinct which

resents the mediæval practice of freely introducing spiritual and unknown causes into working science. In science an appeal to occult qualities must be illegitimate, and be a barrier to experiment and research generally; as when anything is called an Act of God—and when no more is said. The occurrence is left unexplained. As an ultimate statement such a phrase may be not only true but universal in its application. But there are always proximate explanations which may be looked for and discovered with patience. So, lightning, earthquakes, and other portents are reduced to natural causes. No ultimate explanation is ever attained by science: proximate explanations only. They are what it exists for; and it is the business of scientific men to seek them.

To attribute the rise of sap to vital force would be absurd, it would be giving up the problem and stating nothing at all. The way in which osmosis acts to produce the remarkable and surprising effect is discoverable and has been discovered.

So it is always in science, and its progress began when unknown causes were eliminated and treated as non-existent. Those causes, so far as they exist, must establish their footing by direct investigation and research; carried on in the first

instance apart from the long-recognised branches of science, until the time when they too have become sufficiently definite to be entitled to be called scientific. Outlandish Territories may in time be incorporated as States, but they must make their claim good and become civilised first.

It is well for people to understand this definite limitation of scope quite clearly, else they wrest the splendid work of biologists to their own confusion,—helped it is true by a few of the more robust or less responsible theorisers, among whom are some who should be better informed and more carefully critical in their philosophising utterances.

But, as is well known, there are more than a few biologists who, when taking a broad survey of their subject, clearly perceive and teach that before all the actions of live things are fully explained, some hitherto excluded causes must be postulated. Ever since the time of J. R. Mayer it has been becoming more and more certain that as regards performance of work, a living thing obeys the laws of physics, like everything else; but undoubtedly it initiates processes and produces results that without it could not have occurred,—from a bird's nest to a honeycomb, from a deal box to a warship. The behaviour of

a ship firing shot and shell is explicable in terms of energy, but the discrimination which it exercises between friend and foe is not so explicable. There is plenty of physics and chemistry and mechanics about every vital action, but for a complete understanding of it something beyond physics and chemistry is needed.

And life introduces an incalculable element. The vagaries of a fire or a cyclone could all be predicted by Laplace's Calculator, given the initial positions, velocities, and the law of acceleration of the molecules; but no mathematician could calculate the orbit of a common house-fly. A physicist into whose galvanometer a spider had crept would be liable to get phenomena of a kind quite inexplicable, until he discovered the supernatural, *i.e.* literally superphysical, cause. I will risk the assertion that Life introduces something incalculable and purposeful amid the laws of physics; it thus distinctly supplements those laws, though it leaves them otherwise precisely as they were and obeys them all.

We see only its effect, we do not see Life itself. Conversion of Inorganic into Organic is effected always by living organisms. The conversion under those conditions certainly occurs, and the process may be studied. Life appears necessary to the

conversion; which clearly takes place under the guidance of life, though in itself it is a physical and chemical process. Many laboratory conversions take place under the guidance of life, and, but for the experimenter, would not have occurred.

Again, putrefaction, and fermentation, and purification of rivers, and disease, are not purely and solely chemical processes. Chemical processes they are, but they are initiated and conducted by living organisms. Just when medicine is becoming biological, and when the hope of making the tropical belt of the earth healthily habitable by energetic races is attracting the attention of people of power, philosophising biologists should not attempt to give their science away to Chemistry and Physics. Sections D and H and I and K are not really subservient to A and B. Biology is an independent science, and it is served, not dominated, by Chemistry and Physics.

Scientific men are hostile to superstition, and rightly so, for a great many popular superstitions are both annoying and contemptible; yet occasionally the term may be wrongly applied to practices of which the theory is unknown. To a superficial observer some of the practices of biologists themselves must appear grossly super-

stitious. To combat malaria Sir Ronald Ross does not indeed erect an altar; no, he oils a pond,—making libation to its presiding genii. What can be more ludicrous than the curious and evidently savage ritual, insisted on by United States Officers, at that hygienically splendid achievement the Panama Canal,—the ritual of punching a hole in every discarded tin, with the object of keeping off disease! What more absurd, again—in superficial appearance—than the practice of burning or poisoning a soil to make it extra fertile!

Biologists in their proper field are splendid, and their work arouses keen interest and enthusiasm in all whom they guide into their domain. Some of them do their work by intense concentration, by narrowing down their scope, not by taking a wide survey or a comprehensive grasp. Suggestions of broader views and outlying fields of knowledge seem foreign to the intense worker, and he resents them. For his own purpose he wishes to ignore them, and practically he may be quite right. The folly of negation is not his, but belongs to those who misinterpret or misapply his utterances, and take him as a guide in a region where, for the time at least, he is a stranger. Not by such aid is the

universe in its broader aspects to be apprehended. If people in general were better acquainted with science they would not make these mistakes. They would realise both the learning and the limitations, make use of the one and allow for the other, and not take the recipe of a practical worker for a formula wherewith to interpret the Universe.

What appears to be quite certain is that there can be no terrestrial manifestation of life without matter. Hence naturally they say, or they approve such sayings as, 'I discern in matter the promise and potency of all forms of life.' Of all terrestrial manifestations of life, certainly; how else could it manifest itself save through matter? 'I detect nothing in the organism but the laws of Chemistry and Physics,' it is said. Very well: naturally enough. That is what they are after; they are studying the physical and chemical aspects or manifestations of life. But life itself—life and mind and consciousness—they are not studying, and they exclude them from their purview. Matter is what appeals to our senses here and now; Materialism is appropriate to the material world; not as a philosophy but as a working creed, as a proximate and immediate formula for guiding research. Everything be-

yond that belongs to another region, and must be reached by other methods. To explain the Psychical in terms of Physics and Chemistry is simply impossible ; hence there is a tendency to deny its existence, save as an epiphenomenon. But all such philosophising is unjustified, and is really bad Metaphysics.

So if ever in their enthusiasm scientific workers go too far and say that the things they exclude from study have no existence in the universe, we must appeal against them to direct experience. We ourselves are alive, we possess life and mind and consciousness, we have first-hand experience of these things quite apart from laboratory experiments. They belong to the common knowledge of the race. Births, deaths, and marriages are not affairs of the biologist, but of humanity ; they went on before a single one of them was understood, before a vestige of science existed. We ourselves are the laboratory in which men of science, psychologists and others, make experiments. They can formulate our processes of digestion, and the material concomitants of willing, of sensation, of thinking ; but the hidden guiding entities they do not touch.

So also if any philosopher tells you that you do not exist, or that the external world does not

exist, or that you are an automaton without free will, that all your actions are determined by outside causes and that you are not responsible,—or that a body cannot move out of its place, or that Achilles cannot catch a tortoise,—then in all those cases appeal must be made to twelve average men, unsophisticated by special studies. There is always a danger of error in interpreting experience, or in drawing inferences from it; but in a matter of bare fact, based on our own first-hand experience, we are able to give a verdict. We may be mistaken as to the nature of what we see; stars may look to us like bright specks in a dome; but the fact that we see them admits of no doubt. So also Consciousness and Will are realities of which we are directly aware, just as directly as we are of motion and force, just as clearly as we apprehend the philosophising utterances of an Agnostic. The process of seeing, the plain man does not understand; he does not recognise that it is a method of etherial telegraphy; he knows nothing of the ether and its ripples, nor of the retina and its rods and cones, nor of nerve and brain processes; but he sees and he hears and he touches, and he wills and he thinks and is conscious. This is not an appeal to the mob as against the philosopher; it is an appeal to the

experience of untold ages as against the studies of a generation.

How consciousness became associated with matter, how life exerts guidance over chemical and physical forces, how mechanical motions are translated into sensations,—all these things are puzzling, and demand long study. But the fact that these things are so admits of no doubt ; and difficulty of explanation is no argument against them. The blind man restored to sight had no opinion as to how he was healed, nor could he vouch for the moral character of the Healer, but he plainly knew that whereas he was blind now he saw. About that fact he was the best possible judge. So it is also with 'this main miracle that thou art thou, With power on thine own act and on the world.'

But although Life and Mind may be excluded from Physiology, they are not excluded from Science. Of course not. It is not reasonable to say that things necessarily elude investigation merely because we do not knock against them. Yet the mistake is sometimes made. The ether makes no appeal to sense, therefore some are beginning to say that it does not exist. Mind is occasionally put into the same predicament. Life is not detected in the laboratory, save in its

physical and chemical manifestations; but we may have to admit that it guides processes nevertheless. It may be called a catalytic agent.

To understand the action of life itself, the simplest plan is not to think of a microscopic organism, or any unfamiliar animal, but to make use of our own experience as living beings. Any positive instance serves to stem a comprehensive denial; and if the reality of mind and guidance and plan is denied because they make no appeal to sense, then think how the world would appear to an observer to whom the existence of men was unknown and undiscoverable, while yet all the laws and activities of nature went on as they do now.

Suppose, then, that *man* made no appeal to the senses of an observer of this planet. Suppose an outside observer could see all the events occurring in the world, save only that he could not see animals or men. He would describe what he saw much as we have to describe the activities initiated by life.

If he looked at the Firth of Forth, for instance, he would see piers arising in the water, beginning to sprout, reaching across in a strange manner till they actually join or are joined by pieces attracted up from below to complete the circuit (a solid

circuit round the current). He would see a sort of bridge or filament thus constructed, from one shore to the other, and across this bridge insect-like things crawling and returning for no very obvious reason.

Or let him look at the Nile, and recognise the meritorious character of that river in promoting the growth of vegetation in the desert. Then let him see a kind of untoward crystallisation growing across and beginning to dam the beneficent stream. Blocks fly to their places by some kind of polar forces; 'we cannot doubt' that it is by helio- or other tropism. There is no need to go outside the laws of mechanics and physics, there is no difficulty about supply of energy—none whatever,—materials in tin cans are consumed which amply account for all the energy; and all the laws of physics are obeyed. The absence of any design, too, is manifest; for the effect of the structure is to flood an area up-stream which might have been useful, and to submerge a structure of some beauty; while down stream its effect is likely to be worse, for it would block the course of the river and waste it on the desert, were it not that fortunately some leaks develop and a sufficient supply still goes down—goes down in fact more equably than

before: so that the ultimate result is beneficial to vegetation, and simulates intention.

If told concerning either of these structures that an engineer, a designer in London, called Benjamin Baker, had anything to do with it, the idea would be preposterous. One conclusive argument is final against such a superstitious hypothesis—he is not there, and a thing plainly cannot act where it is not. But although we, with our greater advantages, perceive that the right solution for such an observer would be the recognition of some unknown agency or agent, it must be admitted that an explanation in terms of a vague entity called vital force would be useless, and might be so worded as to be misleading; whereas a statement in terms of mechanics and physics could be clear and definite and true as far as it went, though it must necessarily be incomplete.

And note that what we observe, in such understood cases, is an *Interaction* of Mind and Matter; not Parallelism nor Epiphenomenalism nor anything strained or difficult, but a straightforward utilisation of the properties of matter and energy for purposes conceived in the mind, and executed by muscles guided by acts of will.

But, it will be said, this is unfair, for we *know*

that there is design in the Forth Bridge or the Nile Dam, we have seen the plans and understand the agencies at work: we know that it was conceived and guided by life and mind, it is unfair to quote this as though it could simulate an automatic process.

Not at all, say the extreme school of biologists whom I am criticising, or ought to say if they were consistent, there is nothing but Chemistry and Physics at work anywhere; and the mental activity apparently demonstrated by those structures is only an illusion, an epiphenomenon; the laws of chemistry and physics are supreme, and they are sufficient to account for everything!

Well, they account for things up to a point; they account in part for the colour of a sunset, for the majesty of a mountain peak, for the glory of animate existence. But do they account for everything completely? Do they account for our own feeling of joy and exaltation, for our sense of beauty, for the manifest beauty existing throughout nature? Do not these things suggest something higher and nobler and more joyous, something for the sake of which all the struggle for existence goes on?

Surely there must be a deeper meaning involved in natural objects. Orthodox explana-

tions are only partial, though true as far as they go. When we examine each parti-coloured pinnule in a peacock's tail, or hair in a zebra's hide, and realise that the varying shades on each are so placed as to contribute to the general design and pattern, it becomes exceedingly difficult to explain how this organised co-operation of parts, this harmonious distribution of pigment cells, has come about on merely mechanical principles. It would be as easy to explain the sprouting of the cantilevers of the Forth Bridge from its piers, or the flocking of the stones of the Nile Dam by chemiotaxis. Flowers attract insects for fertilisation; and fruit tempts birds to eat it in order to carry seeds. But these explanations cannot be final. We have still to explain the insects. So much beauty cannot be necessary merely to attract their attention. We have further to explain this competitive striving towards life. Why do things struggle to exist? Surely the effort must have some significance, the development some aim. We thus reach the problem of Existence itself, and the meaning of Evolution.

The mechanism whereby existence entrenches itself is manifest, or at least has been to a large extent discovered. Natural Selection is a *vera*

causa, so far as it goes; but if so much beauty is necessary for insects, what about the beauty of a landscape or of clouds? What utilitarian object does that subserve? Beauty in general is not taken into account by science. Very well, that may be all right, but it exists nevertheless. It is not my function to discuss it. No; but it is my function to remind you and myself that our studies do not exhaust the Universe, and that if we dogmatise in a negative direction, and say that we can reduce everything to physics and chemistry, we gibbet ourselves as ludicrously narrow pedants, and are falling far short of the richness and fullness of our human birthright. How far preferable is the reverent attitude of the Eastern Poet:—

> 'The world with eyes bent upon thy feet
> stands in awe with all its silent stars.'

Superficially and physically we are very limited. Our sense organs are adapted to the observation of matter; and nothing else directly appeals to us. Our nerve-muscle-system is adapted to the production of motion in matter, in desired ways; and nothing else in the material world can we accomplish. Our brain and nerve systems connect us with the rest of the physical world. Our

senses give us information about the movements and arrangements of matter. Our muscles enable us to produce changes in those distributions. That is our equipment for human life; and human history is a record of what we have done with these parsimonious privileges.

Our brain, which by some means yet to be discovered connects us with the rest of the material world, has been thought partially to disconnect us from the mental and spiritual realm, to which we really belong but from which for a time and for practical purposes we are isolated. Our common or social association with matter gives us certain opportunities and facilities, combined with obstacles and difficulties which are themselves opportunities for struggle and effort.

Through matter we become aware of each other, and can communicate with those of our fellows who have ideas sufficiently like our own for them to be stimulated into activity by a merely physical process set in action by ourselves. By a timed succession of vibratory movements (as in speech and music), or by a static distribution of materials (as in writing, painting, and sculpture), we can carry on intelligent intercourse with our fellows; and we get so used to

these ingenious and roundabout methods, that we are apt to think of them and their like as not only the natural but as the only possible modes of communication, and to imagine that anything more direct would disarrange the whole fabric of science.

It is clearly true that our bodies constitute the normal means of manifesting ourselves to each other while on the planet ; and that if the physiological mechanism whereby we accomplish material acts is injured, the conveyance of our meaning and the display of our personality inevitably and correspondingly suffer.

So conspicuously is this the case that it has been possible to suppose that the communicating mechanism, formed and worked by us, is the whole of our existence : and that we are essentially nothing but the machinery by which we are known. We find the machinery utilising nothing but well-known forms of energy, and subject to all the laws of chemistry and physics,—it would be strange if it were not so,—and from that fact we try to draw valid deductions as to our nature, and as to the impossibility of our existing apart from and independent of these temporary modes of material activity and manifestation. We so uniformly employ them, in

our present circumstances, that we should be on our guard against deception due to this very uniformity. Material bodies are all that we have any control over, are all that we are experimentally aware of; anything that we can do with these is open to us; any conclusions we can draw about them may be legitimate and true. But to step outside their province and to deny the existence of any other region because we have no sense organ for its appreciation, or because (like the Ether) it is too uniformly omnipresent for our ken, is to wrest our advantages and privileges from their proper use and apply them to our own misdirection.

But if we have learnt from science that Evolution is real, we have learnt a great deal. I must not venture to philosophise, but certainly from the point of view of science Evolution is a great reality. Surely evolution is not an illusion; surely the universe progresses in time. Time and Space and Matter are abstractions, but are none the less real: they are data given by experience; and Time is the keystone of evolution. 'Thy centuries follow each other, perfecting a small wild flower.'

We abstract from living moving Reality a certain static aspect, and we call it Matter; we

abstract the element of progressiveness, and we call it Time. When these two abstractions combine, co-operate, interact, we get reality again. It is like Poynting's theorem.

The only way to refute or confuse the theory of Evolution is to introduce the subjectivity of time. That theory involves the reality of time, and it is in this sense that Prof. Bergson uses the great phrase 'Creative Evolution.'

I see the whole of material existence as a steady passage from past to future, only the single instant which we call the present being actual. The past is not non-existent however, it is stored in our memories, there is a record of it in matter, and the present is based upon it; the future is the outcome of the present, and is the product of evolution.

Existence is like the output from a loom. The pattern, the design for the weaving, is in some sort 'there' already; but whereas our looms are mere machines, once the guiding cards have been fed into them, the Loom of Time is complicated by a multitude of free agents who can modify the web, making the product more beautiful or more ugly according as they are in harmony or disharmony with the general scheme. I venture to maintain that manifest imperfections are thus

accounted for, and that *freedom* could be given on no other terms, nor at any less cost.

The ability thus to work for weal or woe is no illusion, it is a reality, a responsible power which conscious agents possess; wherefore the resulting fabric is not something preordained and inexorable, though by wide knowledge of character it may be inferred. Nothing is inexorable except the uniform progress of time; the cloth must be woven, but the pattern is not wholly fixed and mechanically calculable. Where inorganic matter alone is concerned, there everything is determined. Wherever full consciousness has entered, new powers arise, and the faculties and desires of the conscious parts of the scheme have an effect upon the whole. It is not guided from outside but from within, and the guiding power is immanent at every instant. Of this guiding power we are a small but not wholly insignificant portion.

That evolutionary progress is real is a doctrine of profound significance, and our efforts at social betterment are justified because we are a part of the scheme, a part that has become conscious, a part that realises, dimly at any rate, what it is doing and what it is aiming at. Planning and aiming are therefore not absent from the whole,

for we are a part of the whole, and are conscious of them in ourselves.

Either we are immortal beings or we are not. We may not know our destiny, but we must have a destiny of some sort. Those who make denials are just as likely to be wrong as those who make assertions : in fact, denials are assertions thrown into negative form. Scientific men are looked up to as authorities, and should be careful not to mislead. Science may not be able to reveal human destiny, but it certainly should not obscure it. Things are as they are, whether we find them out or not ; and if we make rash and false statements, posterity will detect us—if posterity ever troubles its head about us. I am one of those who think that the methods of Science are not so limited in their scope as has been thought : that they can be applied much more widely, and that the Psychic region can be studied and brought under law too. Allow us anyhow to make the attempt. Give us a fair field. Let those who prefer the materialistic hypothesis by all means develop their thesis as far as they can ; but let us try what we can do in the Psychical region, and see which wins. Our methods are really the same as theirs —the subject-matter differs. Neither should abuse the other for making the attempt.

Whether such things as intuition and revelation ever occur is an open question. There are some who have reason to say that they do. They are at any rate not to be denied off-hand. In fact, it is always extremely difficult to deny *anything* of a general character, since evidence in its favour may be only hidden and not forthcoming, especially not forthcoming at any particular age of the world's history, or at any particular stage of individual mental development. Mysticism must have its place, though its relation to Science has so far not been found. They have appeared disparate and disconnected, but there need be no hostility between them. Every kind of reality must be ascertained and dealt with by proper methods. If the voices of Socrates and of Joan of Arc represent real psychical experiences, they must belong to the intelligible universe.

Although I am speaking ex cathedra, as one of the representatives of orthodox science, I will not shrink from a personal note summarising the result on my own mind of thirty years' experience of psychical research, begun without predilection —indeed with the usual hostile prejudice. This is not the place to enter into detail or to discuss facts scorned by orthodox science, but I cannot help remembering that an utterance from this

chair is no ephemeral production, for it remains to be criticised by generations yet unborn, whose knowledge must inevitably be fuller and wider than our own. Your President therefore should not be completely bound by the shackles of present-day orthodoxy, nor limited to beliefs fashionable at the time. In justice to myself and my co-workers I must risk annoying my present hearers, not only by leaving on record our conviction that occurrences now regarded as occult can be examined and reduced to order by the methods of science carefully and persistently applied, but by going further and saying, with the utmost brevity, that already the facts so examined have convinced me that memory and affection are not limited to that association with matter by which alone they can manifest themselves here and now, and that personality persists beyond bodily death. The evidence—nothing new or sensational, but cumulative and demanding prolonged serious study—to my mind goes to prove that discarnate intelligence, under certain conditions, may interact with us on the material side, thus indirectly coming within our scientific ken; and that gradually we may hope to attain some understanding of the nature of a larger, perhaps etherial, existence, and of the

conditions regulating intercourse across the chasm. A body of responsible investigators has even now landed on the treacherous but promising shores of a new continent.

Yes, and there is more to say than that. The methods of science are not the only way, though they are our way, of being piloted to truth. '*Uno itinere non potest perveniri ad tam grande secretum.*'

Many scientific men still feel in pugnacious mood towards Theology, because of the exaggerated dogmatism which our predecessors encountered and overcame in the past. They had to struggle for freedom to find truth in their own way; but the struggle was a deplorable necessity, and has left some evil effects. And one of them is this lack of sympathy, this occasional hostility, to other more spiritual forms of truth. We cannot really and seriously suppose that truth began to arrive on this planet a few centuries ago. The pre-scientific insight of genius—of Poets and Prophets and Saints—was of supreme value, and the access of those inspired seers to the heart of the universe was often profound. But the camp-followers, the scribes and pharisees, by whatever name they may be called, had no such insight, only a vicious or a foolish obstinacy; and the prophets of a new era were stoned.

Now at last we of the new era have been victorious, and the stones are in our hands. But for us to imitate the old ecclesiastical attitude would be folly, for it cannot be sustained; humanity would ultimately rise against us, and there would come yet another period of reaction, in which for a time we should be worsted. Through the best part of two centuries there has been a revolt from religion, led by Voltaire and other great writers of that age; but let us see to it that the revolt ceases when it has gone far enough. Let us not fall into the mistake of thinking that ours is the only way of exploring the multifarious depths of the universe, and that all others are worthless and mistaken. The universe is a larger thing than we have any conception of, and no one method of search will exhaust its treasures.

Men and brethren, we are trustees of the truth of the physical universe as scientifically explored: let us be faithful to our trust. Genuine religion has its roots deep down in the heart of humanity and in the reality of things. It is not surprising that by our methods we fail to grasp it: the actions of the Deity make no appeal to any special sense, only a universal appeal; and our methods are, as we know, incompetent to detect

complete uniformity. There is a Principle of Relativity here, and unless we encounter flaw or jar or change, nothing in us responds; we are deaf and blind therefore to the Immanent Grandeur, unless we have insight enough to recognise in the woven fabric of existence, flowing steadily from the loom in an infinite progress towards perfection, the ever-growing garment of a transcendent God.

SUMMARY OF THE ARGUMENT

A marked feature of the present scientific era is the discovery of, and interest in, various kinds of Atomism ; so that Continuity seems in danger of being lost sight of.

Another tendency is toward comprehensive negative generalisations from a limited point of view.

Another is to take refuge in rather vague forms of statement, and to shrink from closer examination of the puzzling and the obscure.

Another is to deny the existence of anything which makes no appeal to organs of sense, and no ready response to laboratory experiment.

Against these tendencies the author contends. He urges a belief in ultimate continuity as essential to science ; he regards scientific concentration as an inadequate basis for philosophic generalisation ; he believes that obscure phenomena may be expressed simply if properly faced ; and he points out that the non-appearance of anything perfectly uniform and omnipresent is only what should be expected, and is no argument against its real substantial existence.

THE BRITISH ASSOCIATION PRESIDENTIAL ADDRESS

1913

Explanatory Notes by the President

Page 1

The Chair of the British Association at Birmingham was to have been filled by Sir William White, F.R.S., late Chief Constructor of the British Navy, who had been made President-Elect at the previous Meeting in Dundee in 1912; but his unexpected death in the spring of 1913 necessitated a fresh election, and the rule of the Association against a local president was broken by the selection of the Principal of the University of Birmingham from the short list of those whose presidency was not likely to be long delayed. This explains the opening paragraph.

Pages 8, 15, and 17

The quotations are from a set of four lectures which Dr. Arthur Schuster gave to the University of Calcutta in 1908, now published by the Cambridge University Press under the title 'The Progress of Physics during 33 years (1875–1908).'

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The immediate predecessor spoken of is Professor Schäfer, the physiologist whose address at Dundee in 1912 on the subject of Life, and on the possibility of artificially producing it or of formulating its origin, excited so widespread an interest. The penultimate predecessor is Sir William Ramsay, the

chemist who presided over the British Association in 1911 at Portsmouth and whose experiments on the influence of radio-active bodies in promoting the transformation of one element into others have been received with varying degrees of caution. The nominated successor spoken of is Professor Bateson, the biologist who before the Birmingham Meeting was nominated, and who at Birmingham was elected, to preside over the British Association during its meeting in Australia, and who is a well-known authority on heredity, especially from the Mendelian point of view.

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The second law of Thermodynamics relates to the working power of heat, and asserts the fact that only bodies at high temperature can be usefully employed as sources of heat. A hydraulic analogy is roughly useful as a first approximation: water at high level can be used to drive machines and give power, but water at average or sea level cannot be so used. Hydraulic working power, therefore, depends on two things, the amount of available water, and its head or height above zero level. So it is also with heat. The work which, by a heat engine like a steam or gas or oil engine, can be extracted from it depends upon its quantity and upon its temperature above some practicable zero, say the ordinary average temperature. Only in the impossible case of the practical zero being the absolute zero—a fearfully low temperature approximated to by skilled experimenters but not actually attained—could all of any given quantity of heat be utilised in the performance of work.

And yet heat is a form of energy, and a form which is liable to be generated as a by-product during every kind of material activity. Energy is protean in change of form, but when once converted into heat it is likely to retain that form, unless some ingenious machine is employed to transform it into other forms of energy and to assist it to do work, as when the vapour

of boiling water is enabled to pump a mine or drive a flywheel by aid of a steam engine. Moreover, there is a tendency for all contiguous bodies, unless specially prevented, to become equal in temperature,—a condition in which no more work can be obtained by any thermal process; and the energy is then said to be degraded or dissipated.

Ultimately therefore, in process of time, it has been suggested that all the energy of the Universe may be expected to take the low form of heat at a uniform temperature, i.e. practically at an exceedingly low, nearly zero, temperature—an epoch being foreshadowed at which every activity will thus ultimately cease.

This dismal foreboding is not, or should not be, set forward with any certainty; because processes whereby energy may be pumped up again, as it were, from lower to higher forms—through the agency of life perhaps, or through the agency of special intelligence for which the crude average terms heat and temperature have no dominating meaning—can be imagined, and it only remains for us to discover them in action somewhere.

A description of how such intelligences could act was first given by Clerk Maxwell, and was vividly elaborated by Lord Kelvin. They are known as 'Maxwell's demons.' Some biologists have suspected the real existence of such agents, in nitrifying bacteria and the like; and although no definite discovery of agencies which will reverse results attributed to the second law of Thermodynamics has yet been made, it would be a mistake to limit the possibility of discovery.

And anyhow the material universe is manifestly in full blast at present; it has not by any means reached the stage of decadence when the sun and all bodies are at one and the same temperature and when every activity has ceased. (Cf. page 54.) The Universe is undoubtedly still a going concern, and yet it

has presumably already lasted an infinite time—for all we know to the contrary.

As to the *first* law of Thermodynamics, that is merely the conservation of energy applied to heat. It was the experimental and quantitative inclusion of heat as a form of energy which allowed the law of Conservation of Energy to be definitely formulated by Joule.

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The most important of Newton's Laws of Motion is that the acceleration of a body is proportional to the resultant force which acts upon it and is in the same direction. The ratio of force to acceleration is called the *mass* or *inertia* of the body, and in ordinary Newtonian Mechanics it is treated as constant. There is a sense in which the remarkable constancy of mass, no matter what happens to it,—in the way of boiling, freezing, decomposition, burning, or solution,—is synonymous with the fundamental postulate of the conservation of matter. But there are other senses in which it is not difficult to allow for a possible variation of mass of a moving body, and hence to get a variable ratio between the force applied to it and the acceleration produced.

Recently it has been found that electrons moving near the speed of light have an increased mass. The result has been arrived at both theoretically and experimentally. It was in fact first predicted mathematically and afterwards confirmed experimentally, and may be taken as quite undoubted.

Mass therefore becomes a function of speed. At all ordinary speeds it is practically constant; but at excessive speeds, far beyond that of a cannon-ball, it begins very slightly to increase; at speeds expressed in thousands of miles per second it begins to increase faster; and at the speed of light it suddenly appears to become infinite—whatever that may

mean. Hence there are some who think that bodies can never move through the ether faster than the velocity of light.

Page 15

In Euclidean Geometry only one straight line can be drawn through a given point parallel to another straight line. That no more than one is possible has never been proven: it was a definite postulate or axiom made by Euclid, but it seemed incapable of proof. Within recent times pure mathematicians have found it possible to devise other more general systems of Geometry, in which two or many such lines can be drawn. Thus Euclidean Geometry, which still appears to suit our own spatial experience very well, can be regarded as a special case of more generalised and comprehensive theoretical systems.

Abstract propositions may be absolutely and completely true: practical experience can approximate to them more or less precisely—in Geometry more precisely than in any other subject. The relation between our systems of thought on the one hand, and our actual experience on the other, is well illustrated by the following quotation from Poincaré:—

'The principles of geometry are not experimental facts. . . . Euclid's postulate cannot be proved by experiment. . . . If Lobatschewsky's geometry is true, the parallax of a very distant star will be finite. If Riemann's is true, it will be negative. These are results which seem within the reach of experiment, and some have hoped that astronomical observations may enable us to decide between the geometries. But what we call a straight line in astronomy is simply the path of a ray of light. If, therefore, we were to discover negative parallaxes, or to prove that all parallaxes are higher than a certain limit, we should have a choice between two conclusions: we could give up Euclidean geometry, or modify the laws of optics, and suppose that light is not rigorously propagated in a straight line. It is needless to add that everyone would look upon this solution as the more advantageous.

Euclidean geometry, therefore, has nothing to fear from fresh experiments.'

Page 18

By 'Euclid's Postulate' is meant the famous postulate or axiom above referred to. It is commonly called 'Axiom 12' in text-books of Euclid elements. It lies at the base of all his doctrine of parallels, and it leads direct to the conclusion that the three angles of a triangle are together equal to two right angles. In fact it is another form of stating that proposition.

Page 19

The 'Preface' referred to is the Introduction by Sir Joseph Larmor, M.P., Lucasian Professor of Mathematics in the University of Cambridge, to the English translation of Poincaré's book called 'Science and Hypothesis' (Scott).

Page 20

Boyle's Law is that the volume of a gas varies inversely with the pressure to which it is subjected. It is a natural consequence of the kinetic theory of gases in its simplest form; but, when considered strictly, it is seen to involve the assumption that the gaseous particles are infinitely small—so small that they can never become the least crowded, however great the pressure,—and further that there is no attractive force or incipient cohesion acting between them, so that never would the effect of pressure be assisted by the action of internal forces. In all actual gases the particles have some intrinsic size of their own; and cohesion becomes sooner or later conspicuous, so that ultimately liquefaction is possible. The further a gas is from showing any sign of molecular cohesion, the more nearly is it considered 'perfect' as a gas. An imperfect gas exhibits already an incipient tendency towards ultimate liquefaction. A corrected form of Boyle's law, applicable not only to imperfect gases

but also to liquids, was devised by the great Dutch physicist Van der Waals, whose treatment, though not even yet finally accurate, was profoundly interesting and instructive.

Page 21

The way in which Kepler discovered his famous laws, from elaborate discussions of the planetary observations of Tycho Brahé, is explained in many books: among others, in the author's own semi-popular volume called 'Pioneers of Science' (Macmillan).

Page 23

The familiar behaviour of a wet sandy beach, when walked over, is very curious; the pressure of a foot dries it, while relaxation of pressure moistens it. In other words, pressure applied to a collection of granular particles tends to increase the spaces between them, and so enables them to hold more water in their interstices. Relaxation and constraint allow the molecules to adjust themselves closer together, and so to squeeze some of the liquid out again. Just opposite to the behaviour of a sponge.

It was on a highly developed superstructure based on this foundation that Professor Osborne Reynolds of Manchester devised his scheme, wherein 'the ether' was supposed to consist of rigid granules in contact, and where 'matter' was the hollows or cavities or regions of greater interstitial capacity existing among them. These regions could readily travel about from one part of the granular structure to another; and this represented the motion of matter in the scheme. Such an ether is very unlike any contemplated by the author.

Page 23

In the 'Physical Review' for August, 1913, Professor R. A. Millikan summarises the results of most recent and trustworthy determinations of molecular magnitudes, and among them of

Avogadro's constant. It may be convenient to quote some of them here :—

Unit of electric charge,	$e = 4{\cdot}774 \times 10^{-10}$ electrostatic units.
Number of molecules per gramme molecule,	$N = 6{\cdot}062 \times 10^{23}$.
Molecules per cubic centimetre of gas at 0° and 76,	$n = 2{\cdot}705 \times 10^{19}$.
Planck's constant	$h = 6{\cdot}62 \times 10^{-27}$ cgs.

The number of H_2O molecules in a cubic centimetre, or say 15 grains, of water is therefore $\cdot 33 \times 10^{23}$; and the number of atoms 10^{23}.

Now 10^{23} cubic centimetres of water weigh 10^{17} tons,
$= 10^8$ cubic kilometres,
$= 25$ million cubic miles,
which would form an ocean 6000 miles long, 2000 miles wide and 2 miles deep,—corresponding therefore very fairly to the North Atlantic Ocean.

Page 25

For a further discussion of incommensurable quantities, and of the impossibility of expressing the majority of physical ratios by any actual number, the author's text-book of Arithmetic and Algebra for General Readers, called 'Easy Mathematics' (Macmillan), may be referred to, in chapter 20 and elsewhere.

Page 27

By the 'degrees of freedom' of a body are meant the independent modes of motion of which it is susceptible. A rigid body has six degrees of freedom, which can be thus enumerated :—a translation or locomotion in each of three directions, the three dimensions of space, up and down, to and fro, right and left; and three rotations, viz. rotation about each of these three directions considered as axes. A *particle* however—mean-

ing a body of no size—has only three degrees of freedom; it can only move in the sense of locomotion, it cannot spin; or rather it may spin as much as it likes and no one will care, its spinning will consume no energy. A perfectly smooth sphere is in much the same predicament; while a smooth dumb-bell has five degrees of freedom, one of its rotations being ineffective. But a tuning-fork, or body susceptible of vibration, has many more degrees of freedom than a rigid body can have; and inasmuch as molecules appear susceptible of vibration, as evidenced by the spectra they emit, it might be supposed that during their ordinary mutual collisions in a perfect gas many of these vibratory movements would be called out and take part in the action. If so, they would be entitled to some of the energy. Indeed a mechanical theory of Clerk Maxwell's proves that after a great number of perfectly random collisions all the energy imparted to a group of similar bodies will be equally shared, on an average, among all the degrees of freedom which they possess (strictly speaking, among all the degrees of freedom which are effective during collision). If, therefore, a given quantity of energy, say heat, is imparted to a gas, it might be expected that it would be split up into so many equal fractions that the translatory energy of the molecules—i.e. the motion upon which 'temperature' depends—would be increased to only an insignificant extent. But it is not so. Experiment on the velocity of sound through various gases shows that the energy imparted by acoustic compression raises the temperature quite decidedly, and is therefore only divided into quite a moderate number of parcels. The number is found to be 3 for monatomic molecules, which therefore to that extent behave like smooth spheres; 5 for diatomic molecules, which therefore behave like smooth dumb-bells; and 6 for molecules consisting of 3 or more atoms, which therefore behave like the general rigid body.

How it can come about that vibratory degrees of freedom are excluded from the sharing, even after the lapse of some time, has long been a subject of controversy; and the fact that it is so has thrown doubt upon the equi-partition theorem itself. The answer suggested by Professor Planck, the eminent physicist of Berlin, is that *fractions* of a unit of energy cannot exist, so that the attempt to subdivide a given portion of energy into an immense number of fractions must fail; only those degrees of freedom that can receive a whole unit can be effective: it is a case of all or none, and those subsidiary modes of motion that can only receive a fraction will not get any.

This is an exceedingly crude and partial account of the initial stages of a large and complex subject, which has been highly developed and is arousing much interest. The unit of energy called 'Planck's constant' enters into very many parts of Physics, and appears to be a reality, however it be accounted for; but I consider that the explanation is to be found in specific properties of matter, and not in the really atomic character of energy itself.

The fact that vibratory molecular energies are not effective in an ordinary gas, are not evoked by ordinary molecular collision, seems to be clear; but the cause of it may be put differently by different people. (See pages 36 and 37.)

Page 30

The reference here is to the extreme doctrine of Professor Weismann, at one time urged upon us, that no characteristic acquired during the life of an individual or series of individuals could be transmitted by inheritance. The truth underlying this doctrine is that unless the sperm or germ cells are affected, mere alteration of body tissue is ineffective for anything beyond the individual. That is manifest. The cells which transmit vitality to the offspring must naturally be modified if

modifications are to be conveyed by them. But it is unreasonable to suppose that deep-seated changes in somatic or bodily structure can be caused without at least running the risk of affecting the more permanent transmission cells also to some extent. Mere defective or injudicious nourishment may have its due influence in this direction. A microscope may not show any difference, some other test must be applied; and by far the most sensitive test for the actual occurrence of such alteration consists in observing whether inheritance is really affected or not. On that question specific experiments are desirable and ought to be made. If surroundings have no effect on the race, except a survival effect,—if the individual can acquire nothing which is transmissible,—it will be very extraordinary; but the test can only be made by direct experiment and observation. Hence we are thrown back on actual experience in every instance, and we cannot generalise and say that no sort of character acquired by the individual can be handed down to his or her descendants. What I suggest in the text is that the discontinuity between reproductive and bodily cells is not likely to be as complete as that.

Page 33

Matter is essentially that which moves. We are acquainted with no portion of matter which is really stationary. A statement of the speed and direction of motion can be included among the elements of description of any piece of matter. Ether in the same sense cannot be moved, but it can be strained. It is strained when a bow is bent; and it is also strained, though less obviously, when a weight is raised, or when gunpowder is kept without the release afforded by pulling the trigger. In all these cases particles of matter are put into constrained positions with reference to each other, and the seat of the static energy involved is the *ether* between and near the particles. When it is

released kinetic energy results, for the matter is then more or less violently moved. Kinetic energy belongs to matter, Static or Potential to ether. The arguments for high density of ether, and for the extraordinarily filmy or gossamer-like character of matter compared to it, will be found in my small book, 'The Ether of Space' (Harper & Bros.)

Page 36

Part of the basis of Planck's theory of *quanta*, or indivisible units of energy, is given, in rudimentary fashion, in the note to Page 27.

Page 39

The Brownian movement, long known as a constant fidget of minute particles suspended in liquid and viewed through a high-power microscope, has acquired great interest of late by the discovery that all the laws of gases apply to those visible material aggregates, consisting as they must of billions of atoms, as well as to the almost infinitely smaller and quite invisible things, the atoms and molecules themselves. An interesting account of all these matters will be found in a scientific book by M. Jean Perrin, Professor of Physical Chemistry in the University of Paris, which has been translated into English by Mr. Soddy, F.R.S., and published by Taylor & Francis under the title: 'Brownian Movement and Molecular Reality.'

Pages 40 *to* 58

It is as difficult to convey to general readers some idea of the Principle of Relativity, and its virtual supersession of the Ether, as it was to explain about the equi-partition of energy and *quanta*, but a rough attempt may again be made. It has long been a moot point whether the Ether was or was not carried forward to any extent by moving matter. The question was discussed mathematically by Fresnel at the beginning

of last century; and Fizeau found experimentally that light travelled quicker down running water than when it travelled against the stream—about half (more accurately 7/16ths) of the speed of the water being added to the light,—quite in accordance with the teachings of Fresnel. But whether this sort of effect could be detected in the immediate *neighbourhood* of moving matter, without going actually inside it, was quite unknown; and in and about 1892 and subsequent years at Liverpool I made a serious attempt to examine the question experimentally. The experiments are described in the Philosophical 'Transactions' of the Royal Society for 1893 and 1897, and the conclusion is that when a mass of iron or steel is spinning so fast that it is liable to fly to pieces, and when light is sent by mirrors round and round many times in its immediate neighbourhood,—so close as to be actually grazing the spinning disks in some instances,—not the slightest effect of acceleration is manifested by the beam of light, however delicately it be tested by means of interference bands. Interference is arranged between beams which have travelled half with and half against the motion, for many yards; but, after spurious results are allowed for, there is no shift of the bands; proving that the velocity is not affected by so much as one-tenth of one per cent of the velocity of the moving matter. Practically we may say that the Ether of space is never carried forward—presumably not even by a planet;—for the Fizeau effect, properly interpreted, means the same thing.

Professor Michelson of Chicago, however, one of the most brilliant experimental physicists in America—which is saying a good deal—tried a totally different experiment, examining whether light sent to and fro over a fixed distance in the direction of the earth's planetary motion through space, took any longer on its double journey than it did when sent to and fro over the same distance across the motion. The result was

likewise negative: no difference could be perceived; though the delicate experiment was performed with the utmost care and skill, and was afterwards repeated still more elaborately by Professor Michelson and Mr. Morley in collaboration. This negative result, however, is in apparent or superficial opposition to the other negative result: it seemed difficult to suppose that they could both be true. Because if the Ether is not carried forward by the earth at all, it must be relatively streaming past the earth with a speed of many miles per second, as many as 30 sometimes; and accordingly an effect ought to be observed. The negative result of Michelson, therefore, superficially suggests that the Ether in the neighbourhood of the earth is stagnant—which in this case is the opposite of stationary—i.e. that it clings to the earth and is carried forward by it. Many difficulties would arise if that were true, and the theory of ordinary astronomical aberration would be complicated; the Ether would no longer be behaving as a perfect fluid, but would be exhibiting what is called viscosity. Planets could hardly move through it without resistance, and astronomical theory would have to be overhauled. Moreover, my experiment with steel disks, designed to detect a trace of viscosity, failed to show any: in fact negatived the idea. So the FitzGerald-Lorentz hypothesis was devised in order to explain the negative result of Professor Michelson in another way, by postulating a minute change of shape or distortion of all bodies as they move through the Ether of space at any excessive speed; and there is a great deal to be said in favour of such a hypothesis. Some physicists, however, consider it only a hyperingenious and imaginative device of evading awkward and irreconcilable facts. Many other experiments have been made to detect the effect of an etherial movement relatively to the earth; and they have all uniformly failed. So at length Professor Einstein first, and now many others, have supposed that the

Universe is so adjusted that an observation of this kind is for ever impossible. They boldly make the postulate or axiom that although motion of matter with respect to matter is readily perceived, motion of matter with respect to ether is impossible to observe and is in fact meaningless. They formulate the principle that nothing but relative motion of pieces of matter with respect to each other can ever be detected, and that no change in the velocity of light can ever be observed except when there is relative motion of matter. This principle, enthroned as the *Principle of Relativity*, has become the foundation of a mathematical erection, with far-reaching and in some cases surprising and almost paradoxical consequences, affecting the going of clocks and even the nature of Time.

The difficult part of the theory of Relativity is connected with the deduction of all these remarkable consequences: the fact that motion with respect to the ether is difficult to observe, together with the familiar fact of the extreme ease of observing the relative motion of pieces of matter with respect to each other, constitutes the superficial and primary foundation for the Principle of Relativity. The Principle goes on to translate *difficulty*, in the first case, into *impossibility*, and then to make elaborate mathematical deductions.

The mode in which I would explain the admitted fact that nothing but relative motion of pieces of matter has so far been observed, is indicated on pages 44 *et seq.*; the cause of all the negative experimental results, on which foundation of the Principle rests, is to be found in the complete *uniformity* of the ether and in its universal activity and prevalence. This has led to the Principle which virtually denies its existence. The last thing that a deep-sea fish could discover would be water. (See also page 93.)

Page 43

The concluding paragraph on this page is another reference

to my Ether-gripping experiment, referred to in the above note and page 34, and briefly described in my book 'The Ether of Space.' The word 'hope' can only be used in a special sense in connexion with any experiment: the object of that experiment was of course to ascertain whether the ether is to any degree attached to moving matter or not. I was not aware of having any expectation of a positive result. What I was anxious about was to make sure of a definite answer one way or the other.

Page 46

Rotation of an isolated non-rigid body can be detected by its bulging under centrifugal force: as when a bucket is twisted the liquid surface becomes parabolic. Again, the non-spherical shape of the earth or of Jupiter is immediately connected with their periods of rotation, i.e. with the length of their respective days. The oblateness of the earth was thus quantitatively predicted by Newton long before it was geodetically observed by accurate surveying. See, for instance, 'Pioneers of Science,' previously referred to.

Page 50

The pressure exerted by light was predicted by Clerk Maxwell, and by Bartoli, and was first observed by Nicholls and Hull. The consequent or associated momentum conveyed by a wave front, and a number of the effects deducible from this process, have been worked out most instructively by Professor J. H. Poynting, who has published a little book on the subject called 'The Pressure of Light' (S.P.C.K.)

Pages 56 *and* 57

The Michelson-Morley experiment detects no difference between a journey to and fro and a journey right and left, if one is facing the hypothetical ether stream presumably caused relatively to the earth by its rapid motion through space, and

if one is sending a beam of light in these directions by means of mirrors mounted on some rigid body, such as a block of stone or metal. (See also Note to pp. 40–58.) But elementary arithmetic shows that it *ought* to take slightly longer, going up and down the stream, than there and back across it. Hence, either there is no such ether stream, or else the block on which the mirrors and other optical appliances are mounted changes, so as to be shorter by a compensating amount in the direction of motion as compared with its breadth in the transverse direction. The required change is exceedingly small, equivalent to a shrinkage of three inches in 8000 miles, yet on the electric theory of matter something of this magnitude almost certainly ought to occur. This is the famous FitzGerald-Lorentz hypothesis, referred to in the text. (See pp. 49 and 58; also my book 'Electrons,' chapter 16, about cohesion.)

The algebraic expression given on page 58 for the amount of the change is not quite the usual orthodox expression for it; but it is one which I have reason for putting forward, and is not a misprint.

Page 68

The longstanding puzzle as to how vegetable sap is raised against gravity from the ground to the tops of the highest trees has been practically settled by recent workers, notably by Professor H. H. Dixon, of Trinity College, Dublin, who has made a clear statement of the way in which osmosis, or molecular diffusion through semi-permeable membranes, enables it to occur.

Page 72

Higher plants can only assimilate inorganic material after it has been first incorporated into more lowly organisms. Harsh treatment of a soil is found helpful to the beneficent and manuring bacteria; for, being low in the scale of existence, they are hardier and more resistant to hostile influences than the

still microscopic foes which feed upon them. Wherefore treatment which slays the one indirectly benefits the other. This explanation is not yet proven, but the facts suggest it as likely.

Page 72

The larval stage of the mosquito is passed in water, and the larvæ cling to and perforate the surface in order to breathe. If the surface is oiled the surface tension is diminished, the surface does not support them, and they keep on sinking till they drown. But not every puddle or dribble of liquid can be oiled, and so breeding-places can be guarded against partly by drainage and partly by allowing no unperforated vessel to remain as a trap for accumulated water.

Page 75

The ancient arguments of Zeno and other philosophers are of the nature of a *reductio ad absurdum*, and were directed against the trivial arguments of certain opposing philosophers. The contention that motion cannot occur because an object must be in either one place or another, and the contention that a quick runner cannot pass a slow one because the space between them is infinitely subdivisible and some time is needed to cover every division, were not put forward as statements of fact absurdly contrary to experience, but as arguments in favour of continuity of space and against a static idea of time. All these ancient paradoxes are really ingenious weapons of dialectic, and are not to be taken as a sign of philosophic stultification, as unfortunately they sometimes are.

Page 77

By a catalytic agent is signified in Chemistry something which promotes a process or chemical change without taking part in it: that is to say, a material substance which by its

presence facilitates a reaction while itself remaining unchanged, apparently, or at any rate ultimately, inert. Such instances are very common; one of the best known being the action of manganese dioxide in the liberation of oxygen from potassic chlorate. If everyday illustrations are helpful, a broker may be called a catalytic agent in a Stock Exchange transaction; and the same epithet might be applied to a parson at a wedding.

Now in the various interactions which occur between the two great conserved entities, energy and matter, life and living bodies seem to act in a catalytic fashion; for they contribute no energy, but they direct it, and thereby facilitate operations that without their aid would have been difficult or impossible. The simple act of lifting a fallen body may be adduced as an instance of such an operation, without ascending to the more striking case of engineering works; while in a chemical or physical or biological laboratory innumerable so to speak 'unnatural' things are done, and the ordinary operations of nature designedly interfered with.

Page 81

Some examples of purely inorganic crystallisation, especially when viewed by polarised light, are extraordinarily beautiful, and sometimes simulate the appearance of gorgeous vegetation or of feather markings. It must be admitted that to draw a clear line between such purely automatic molecular arrangements and those which are brought about through the agency of life is by no means easy. The material world itself when closely examined is found to be saturated with beauty as well as with law and order, and it is far from surprising that the purely inorganic realm has to many investigators seemed sufficient to account for everything. Until we know more clearly in what way life acts as it does, until we understand more fully the method of the interaction of mind and matter,

these things must remain a matter of empirical experience—admitted but not explained. The formulation of a satisfactory theory must await the attainment of deeper knowledge. Meanwhile all the careful investigation that is going on, in biology, in psychology, and in every direction, is all to the good—by whatever provisional hypothesis the worker is guided.

Page 83

The quotation here, and that on page 85 also, are from the writings of Rabindranath Tagore in his book called 'Gitanjali,' which he wrote both in Hindustani and in English, and which constitutes an implicit message of peace and harmony and mutual understanding from the East to the West.

Page 84

Professor Münsterberg for instance has indicated his feeling that although he is open to conviction about the reality of telepathy if he be forced to it by absolute demonstration, yet the fact would be so novel, the revolution so great, and the disarrangement of organised knowledge so profound, that almost any other hypothesis seems to him preferable and more likely. I admit that telepathy when universally accepted will constitute an important enlargement of human knowledge, as well as an addition to recognised human powers, but I cannot see that it is psychologically and scientifically so revolutionary as it evidently appears to the eminent philosopher of Harvard. I trust that as opportunity offers he will pursue his studies in this domain and will ultimately be convinced by facts.

Page 84

It appears to me very probable that telepathy or thought transference is a form of direct communication between mind and mind, apart from the usual physical or material concomi-

tants. If so, it is a vitally important discovery, and should be confirmed by each one for himself through careful experiment and observation, whenever opportunity occurs; so that gradually it may be recognised as an assured fact, not only by the few who have as yet taken the trouble to study it, but by all.

Communication with discarnate minds is a further step, and needs separate and most critical proof, but if any such communication ever occurs it would seem to be rendered possible by the exercise of telepathic power. Such communication does not anyhow appear easy, but it is probably by some method akin to telepathy that it can sometimes be brought about. Mental and spiritual operations, such as prayer, realised as efficacious by religious people, appear to be partially of this nature.

Page 86

The semi-jocular parable about 'Poynting's Theorem' here interjected will only be appreciated by physicists. It is a mathematical theorem that when electric and magnetic fields are superposed at right angles to each other a third element is at once introduced,—an element of progression or advance of energy at right angles to both, and of value equal to their vector product. It is in this way that light advances, and that telegraphic messages, wireless and other, are conveyed. Of the three elements, electricity, magnetism, and motion, when any two are supplied the third necessarily supervenes. This is the basis of ordinary dynamos and of electric motors, as well as of many other more recondite things. The Theorem with many illustrations was published in the Philosophical 'Transactions' of the Royal Society for 1884.

Page 87

The human evil in the world can be regarded as the price to be paid for human freedom. The highest product of evolu-

tion is not a set of automata mechanically constrained or coerced to go right, but human beings, knowing good and evil, who can go wrong if they choose, and whose will to do right gradually develops; at a cost in suffering and error, great indeed, but not too great for the worthwhileness of the ultimate product. This point of view is more fully explained in my book 'Man and the Universe' and other such writings.

The outstanding difficulty always felt about reconciling freedom with fixed law is dealt with in the first article of my book called 'Modern Problems' (Methuen), where what I have to say, whether it be considered useful or not, represents or summarises the results of very careful consideration.

Page 90

It will be said, it has indeed been frequently said, that the evidence ought here to have been adduced. To this there are two fairly obvious replies. The first is that the evidence for any kind of scientific statements is quite inappropriate to an address; a summary and an allusion is all that can be allowed, and nothing more is attempted in any part of an address of this kind; study of the evidence is necessarily a long and laborious undertaking. The second is that even though some parts of the evidence were offered, not in an address but in a paper to one of the Sections, it would as yet not be admitted. The attempt has been made. Sir William Barrett in the year 1876 read a paper on the evidence for telepathy before the British Association at Glasgow, but its publication was prevented.

No, the time is not ripe for discussing the evidence for supernormal psychical experience except in connexion with a scientific society formed for the purpose. The subject is only emerging from the stage expressed by the first paragraph on page 69, though under the guidance of the critical leaders of the Society for Psychical Research it is emerging rather fast.

The members of that Society are aware that the evidence already published—the carefully edited and sifted evidence published by their own organisation—occupies some 40 volumes of Journal and Proceedings; and some of them know that a great deal more evidence exists than has been published, and that some of the best evidence is not likely to be published,—not yet at any rate. It stands to reason that the best evidence must often be of a very private and family character. Many, however, are the persons who are acquainted with facts in their own experience which appeal to them more strongly than anything that has ever been published. No records can surpass first-hand direct experience in cogency.

Nevertheless members of the Society for Psychical Research are also aware, or ought to be, that no one crucial episode can ever be brought forward as deciding such a matter. That is not the way in which things of importance are proven. Evidence is cumulative, it is on the strength of a mass of experience that an induction is ultimately made and a conclusion provisionally arrived at; though sometimes it happens that a single exceptionally strong instance, or series of instances, may clinch it for some individual.

But indeed the evidence in one form and another has been crudely before the human race from remote antiquity, only it has been treated in ways more or less obfuscated by superstition. The same sort of occurrences as were known to Virgil and many another seer—the same sort of experiences as are found by folk-lore students, not only in history but in every part of the earth to-day—are happening now in a scientific age and sometimes under scientific scrutiny. Hence it is that from the scientific point of view progress is at length being made, and any one with a real desire to know the truth need not lack evidence if he will first read the records with an open mind and then bide his time and be patient till an opportunity

for first-hand critical observation is vouchsafed him. The opportunity may occur at any time: the readiness is all. Really clinching evidence in such a case is never in the past; a prima facie case for investigation is established by the records, but real conviction must be attained by first-hand experience in the present.

Page 91

The quotation is from the writings of Symmachus, an important personage in the 4th century A.D.; not the Pope of that name, but a pagan proconsul rather hostile to official Christianity. The reference is *Epp.* x. 54. The passive voice of the verb is not a misprint; it appears intended to convey the sense not merely of arriving at truth but of being assisted or guided thereto.

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